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Invasive Exotic Plant Monitoring Protocol for the Heartland Network Inventory and Monitoring Program

Natural Resource Report NPS/MWR/HTLN/NRR—2007/018

A Heartland Network Monitoring Protocol



protecting the habitat of our heritage



Heartland
Network

Natural Resource Monitoring

ON THE COVER

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

Invasive Exotic Plant Monitoring Protocol for the Heartland Network Inventory and Monitoring Program

Natural Resource Report NPS/MWR/HTLN/NRR—2007/018

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Executive Summary

Invasive exotic species fragment native ecosystems, displace native plants and animals, and alter ecosystem function. Invasive species are second only to habitat loss as threats to global biodiversity (Scott and Wilcove 1998). Such species negatively affect park resources and visitor enjoyment by altering landscapes and fire regimes, reducing native plant and animal habitat, and increasing trail maintenance needs. Recognizing these challenges, Heartland Network parks identified invasive exotic plants as the highest ranking vital sign across all network parks.

Given the need to provide early detection of potential invasive exotic plants (IEPs) and the size of network parks, the Heartland I&M Network opted to allocate available sampling effort to maximize the area searched. With this approach and the available sampling effort in mind, we developed realistic objectives for the IEP monitoring protocol. The monitoring objectives are:

1. Annually update a watch list of IEPs known to occur in network parks and a watch list of potential IEPs that may invade network parks in the future.
2. Provide early detection monitoring for all IEPs on the watch lists.
3. Search at least 3 % and up to 40 % of the reference frame for IEP occurrences in each park.
4. Estimate the abundance of IEPs in each park.
5. To the extent possible, identify temporal changes in the distribution and abundance of IEPs known to occur in network parks.

IEP watch lists are developed using the best available and most relevant state, regional, and national exotic plant lists. The lists are generated using the PriorityDB database. We designed the park reference frames (i.e., the area to be monitored) to focus on accessible natural and restored areas. The field methods vary for small parks and large parks, defined as parks with reference frames less than and greater than 350 acres (142 ha), respectively. For small parks (ARPO, GWCA, HEHO, HOCU, HOME, LIBO, PIPE), surveyors make three equidistant passes through search units, approximately 2-acres (0.8 ha) in size. For large parks, surveyors record each IEP encountered along 200 m (EFMO, WICR) or 400 m (CUVA, HOSP, PERI, TAPR) transects. The cover of each IEP encountered in search units or along transects is estimated using the following cover scale: 0=0, 1=0.1-0.9 m², 2=1-9.9 m², 3=10-49.9 m², 4= 50-99.9 m², 5=100-499.9 m², 6= 499.9-999.9 m², and 7=1,000-4,999.9 m². The field data are managed in the LocationDB database. Monitoring is scheduled to revisit most parks every five years. The network will report the results to park managers and superintendents after completing IPE monitoring.

Acknowledgements

The National Park Service's Inventory and Monitoring Program provided funding for the invasive exotic plant monitoring protocol and monitoring implementation. We gratefully acknowledge helpful reviews from Dr. Penny Latham, Susan O'Neil, Dr. Dennis Odion, Dr. Lisa Rew, and Dr. Bradley Welch. The protocol conforms to WASO guidelines for NPS Inventory and Monitoring Program protocols (Oakley et al. 2003). This protocol uses sections of text without citation, but with permission from the draft document, Early Detection of Invasive Plants: A Handbook, Paul H. Geissler and Bradley A. Welch, editors. Brad Welch and Susan O'Neil authored the paragraphs taken from that document. We thank Kevin James, Mike Williams, and Gareth Rowell for assistance with database development.

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Invasive Exotic Plant Monitoring Protocol for the Heartland Network Inventory and Monitoring Program

1. Background and Objectives

1a. Background and history

“A native plant, within a specified geographical range of interest, is a plant species (or other plant taxon) currently or historically present there without direct or indirect human intervention” (Morse 2007). Exotic species would not meet this definition. Invasive exotic plants (IEPs) are a subset of exotic plants “whose introduction does or is likely to cause economic or environmental harm or harm to human health” (Executive Order 13112). With the need for strategic control approaches in mind, this monitoring protocol detects early invasions, identifies existing invasions, and, to the extent possible, tracks changes in the abundance and distribution of IEPs in parks.

1b. Rationale for selecting this resource to monitor

Overview of the invasive exotic plant problem

IEP species fragment native ecosystems, displace native plants and animals, and alter ecosystem function. Invasive species are second only to habitat loss as threats to global biodiversity (Scott and Wilcove 1988). IEPs negatively affect park resources and visitor enjoyment by altering landscapes and fire regimes, reducing native plant and animal habitat, and increasing trail maintenance needs. IEPs can also threaten historic viewsheds, park buildings, and adjacent non-park lands. Given the extraordinary biodiversity of National Park units, managers must ensure that the parks protect native species.

National Parks are deluged by new IEPs arriving through a variety of pathways. Predictable pathways include roads, trails, and riparian corridors. Sudden pathways include long distance dispersal through cargo containers and air freight. Anthropogenic pathways include horticultural escapes and seeds carried on shoes, in restoration seed mixes, and many more. Exotic plants invade an estimated 4,600 acres (1862 ha) of public lands each year in the United States (Asher and Harmon 1995), significantly altering state flora. For example, exotic plants comprise an estimated 43% and 36% of the flora of the states of Hawaii and New York, respectively (Rejmanek and Randall 1994). IEPs infest an estimated 2.6 million (1,052,183 ha) acres of the 83 million acres (33,588,908 ha) managed by the NPS. For the NPS, the consequences of these plant invasions present a significant challenge to the agency’s ability to maintain natural resources “unimpaired for the enjoyment of future generations.”

More NPS lands are infested daily despite diligent efforts to curtail the problem. Impacts from IEP species have been realized in most parks, resulting in an expressed need to control existing infestations and restore affected ecosystems. Additionally, there is a growing urgency to be proactive—to protect resources not yet impacted by current and future IEPs (Marler 1998). IEPs certainly will continue to be a management priority for the National Parks well into the future. In 2006, the NPS drafted an Invasive Species Action Plan (NPS 2006) to address how the agency

will fight current and future invasions. This document addressed strategies ranging from prevention and early detection to monitoring to restoration to public outreach and education.

Strategic management of invasive exotic plants

In their review of the status of biotic invasions, Mack et al. (2000) stated in no uncertain terms that “control of biotic invasions is most effective when it employs a long-term, ecosystem-wide strategy rather than a tactical approach focused on battling individual invaders.” Effective control of IEPs, then, requires managers to match management strategies with the task at hand. In other words, early detection methods should be employed to find and subsequently eradicate incipient populations of IEPs while these measures are still feasible and cost effective. Control strategies should be applied to existing populations that require a more substantial resource investment to mitigate associated impacts. Containment measures should be used when populations have become so entrenched that removal and effective control are impractical.

Detecting invasive species before they become established has been a longstanding practice in agriculture, with point-of-entry and distribution inspections, insect traps, and nursery certification, but has not been widely used by land managers in invasive species monitoring and management programs. Early detection followed by rapid response is cost-effective in that it removes a species before it establishes within a park (OTA 1993, Myers et al. 2000, Timmins and Braithwaite 2001, Harris et al. 2001, Rejmanek and Pitcairn 2002). In addition to saving money, early detection and rapid response efforts minimize ecological damage by preventing habitat fragmentation and ecosystem degradation associated with large or widespread invasive species populations.

Invasive exotic plants in the Heartland Inventory and Monitoring Network

In response to National Park Service (NPS) policies calling for a strategic approach to IEP management, the parks in the Heartland Inventory and Monitoring Network (Heartland I&M Network) recognized IEP management and monitoring as a network priority. During the vital signs selection process in 2003, nine parks (CUVA, EFMO, GWCA, HEHO, HOCU, HOME, LIBO, OZAR, PERI, see Table 1 for park codes) identified IEPs as their most important management issue, two parks (TAPR, WICR) identified IEPs as their second most important management issue, and PIPE identified IEPs as its third most important management issue (DeBacker et al. 2004, see Table 1 for park codes). During this process, IEP monitoring was recognized across all network parks as the most important shared monitoring need. Recognizing the shared ecological characteristics of network parks provides a basis for addressing common IEP management issues.

The parks in the Heartland I&M Network vary with respect to size and vegetation (Table 1, Appendix A). Network parks include five parks less than 250 acres (101 ha) in size, five parks from 750 (304 ha) to 5,000 acres (2023 ha) in size, and three parks greater than 5,000 acres (2023 ha) in size (Table 1). The geographic range of the network parks spans a number of physiographic provinces (Fenneman 1946), ecoregions (Bailey 1995), and potential natural vegetation types (Küchler 1985). Based on these classifications, the thirteen network park units were grouped to reflect common ecological conditions for planning IEP monitoring (Table 1, Appendix A).

An overview of park species lists and planning documents highlights three points: 1) network parks support vegetation resources of tremendous cultural and natural resource significance, 2) network parks contain some of the most recalcitrant IEPs found in forests (garlic mustard, kudzu, Japanese honeysuckle, multiflora rose, privet), grasslands (sericea lespedeza, smooth brome, leafy spurge, sweet clover), and wetlands (reed canary grass, common reed, purple loosestrife, Japanese knotweed), and 3) the vegetation in these parks is susceptible to numerous plant invasions. The need to detect new invasions and track existing invasions necessitated the development of the IEP monitoring protocol for the Heartland I&M Network.

Table 1. Ecoregions of Heartland Inventory and Monitoring Network parks.

Ecological Group	Park Units	Code	Acres (Ha)
Eastern Deciduous Forest	Cuyahoga Valley National Park	CUVA	32,861(13,298)
	Effigy Mounds National Monument	EFMO	2,526 (1,022)
	Hopewell Culture National Historic Park	HOCU	1,170 (473)
	Lincoln Boyhood National Memorial	LIBO	200 (81)
Mississippi Embayment	Arkansas Post National Memorial	ARPO	758 (307)
Ozark Plateau	George Washington Carver National Monument	GWCA	210 (85)
	Pea Ridge National Military Park	PERI	4,300 (1,740)
	Wilson's Creek National Battlefield	WICR	1,750 (708)
Tallgrass Prairie	Homestead National Monument of America	HOME	195 (79)
	Herbert Hoover National Historic Site	HEHO	187 (76)
	Pipestone National Monument	PIPE	282 (114)
	Tallgrass Prairie National Preserve	TAPR	10,894 (4,409)

1c. Measurable objectives

Given the need to provide early detection of potential IEPs and the size of network parks, the Heartland I&M Network opted to allocate available sampling effort to maximize the area searched. With this approach and the available sampling effort in mind, we developed realistic objectives for the IEP monitoring protocol. The monitoring objectives are:

1. Annually update a watch list of IEPs known to occur on network parks and a watch list of potential IEPs that may invade network parks in the future.
2. Provide early detection monitoring for all IEPs on the watch list.
3. Search at least 3 % and up to 40 % of the reference frame for IEP occurrences on each park.
4. Estimate the abundance of IEPs in each park.
5. To the extent possible, identify temporal changes in the distribution and abundance of IEPs known to occur on network parks.

6. To the extent possible, characterize relationships between habitat variables and IEP distribution and abundance.

The objectives are specifically designed to assist managers in identifying high priority invasive plants, planning invasive plant management, and assessing management in an adaptive sampling framework.

2. Sampling Design

2a. Rationale for selecting species for monitoring

A great number of exotic plant prioritization and risk assessment protocols have been developed, often designed for particular purposes or specific geographic regions. The Alien Plant Ranking System evaluates plant life-history, ecological effects, and management feasibility to prioritize control efforts in parks (Hiebert and Stubbendieck 1993). NatureServe's I-ranks use extensive biogeographical information as criteria to rank plant invasiveness at local, regional, national, and global scales (Morse et al. 2004). The California Exotic Pest Plant Council list relies heavily on expert opinion to assess ecosystem effects and plant invasion potential (Warner et al. 2003). The Invasive Plants Association of Wisconsin's Working List of the Invasive Plants of Wisconsin was developed through a systematic survey of plant experts (IPAW 2003). Each of these systems provides a well-conceived model for ranking invasive plants. Other less formal lists draw on experience across a range of resource management disciplines. As an example, state and federal noxious weed lists have historically targeted agricultural pest plants.

We developed an exotic plant prioritization database (PriorityDB) to prioritize IEP species for monitoring on network parks. The PriorityDB provides four key pieces of information: 1) a list of species that are considered exotic or invasive based on numerous state and national lists (see lists below), 2) a list of exotic plants in each state (based on USDA Plants database and state lists), 3) a list of exotic plants in each park (based on NPSpecies database), and 4) a designation of exotic plants as a high priority based on a consensus of the state and regional lists. The priority ranking is an attempt to distinguish exotic plants that are likely to be highly invasive in natural areas from exotic plants that are naturalized or highly disturbance-dependent and less likely to invade intact natural areas. For the purposes of this protocol, IEPs are defined as high priority exotic plants.

The following exotic plant lists were consulted:

1. Missouri Vegetation Control Manual by Tim E. Smith, Missouri Department of Conservation (<http://www.mdc.mo.gov/nathis/exotic/vegman/>).
2. Illinois Native Plant Society List (<http://www.inhs.uiuc.edu/inps/exotics.html>).
3. Invasive Plants Association of Wisconsin Working List (<http://www.ipaw.org/newsletters/issue4.pdf>).
4. Draft list of non-native plant species of concern in Arkansas. Claytonia 23:6-7. C.T. Witsell and J. Jardine.
5. Nonnative Invasive Plants of Southern Forests by James H. Miller, United States Forest Service (<http://www.invasive.org/eastern/srs/>).

6. Nebraska watch list of plants that are highly invasive and difficult to control by Nebraska Weed Control Association (<http://www.newweed.org/watchlist/wlindex.htm>).
7. Minnesota Department of Natural Resources (<http://www.dnr.state.mn.us/invasives/index.htm>).
Ohio's Top Ten Invasives (<http://www.dnr.state.oh.us/tabid/2007/default.aspx>)
8. Invasive Plants in Indiana, a joint publication of the of Indiana Department of Natural Resources, The Nature Conservancy, Indiana Native Plant Society, United States Forest Service, Indiana Academy of Science (<http://www.inpaws.org/InvasivePlants.pdf>).
9. Missouri Exotic Pest Plant List from the Missouri Botanical Garden (<http://www.mobot.org/MOBOT/research/mepp/ratings1.html>). Ranks A-D.
10. Plant Conservation Alliance list for plants occurring in AR, IA, IL, IN, KS, MO, MN, NE, OH (<http://www.nps.gov/plants/alien/list/all.htm>).
11. NatureServe's Data on U.S. Invasive Species: Impact Assessments with Invasive Ranks (I-Ranks) (<http://www.natureserve.org/explorer/>).
12. Invasive Plants of the Upper Midwest by E.J. Czarapata, 2005. Ranks: A=major concern, B=lesser concern, C=potential concern.
13. Invasive Plants in the Chicago Region from the Chicago Botanic Garden: (<http://www.chicagobotanic.org/research/conservation/invasive/chicago/index.php>).
Ranks: E=evaluate, R=remove, P=phase-out, W=watch list.
14. New Invasive Plants in the Midwest list from the Midwest Invasive Plant Network (<http://www.mipn.org/New%20Invasives%20Flyer.pdf>).
15. An Invasive Species Assessment Protocol: Evaluating Non-Native Plants for Their Impact on Biodiversity. Version 1. Document.
<<http://www.natureserve.org/getData/plantData.jsp#InvasivesProtocol>>. Morse, L. E., J. M. Randall, N. Benton, R. D. Hiebert, and S. Lu. 2004 and
<<http://www.natureserve.org/explorer/>>.

Within PriorityDB, the designation of an exotic plant as a high priority (i.e., an IEP) species is based on a consensus of the various lists. All plant species with a high invasive rank (Morse et al. 2004) and all plants on the early detection-oriented New Invasive Plants in the Midwest list were marked as a high priority. Beyond these lists, the high priority designation was reserved for exotic plants included on a number of lists with some caveats. The Invasive Plants in Arkansas Natural Areas list and Nonnative Plants of Southern Forests list were given greater consideration because only these lists cover many of the IEPs with southern affinities. Although the prioritization is subjective, this approach offers several advantages: 1) the decision is based on multiple lists and does not rely on any single listing or ranking approach, and 2) the decision does not use a scoring system in an attempt to make a subjective approach seem more objective. Rather, this system supposes that priority designation will be revisited and modified over time based on new information, but assumes that a core of the most problematic plants will continue to be designated as high priority IEPs. Focusing on a large number of species requires retaining staff or contracting botanists with plant taxonomic skills.

The modular structure of PriorityDB and the use of the best existing databases are its primary advantages. The structure allows data tables to be individually updated as needed. Metadata for state and regional lists are documented. USDA Plants database and NPSpecies use the Integrated Taxonomic Information System (ITIS), the national standard for taxonomic

information. NPSpecies is the standard I&M database for species occurrence records in the National Park System. The certification process for NPSpecies increases the accuracy of records and maintains current nomenclature. Species occurrence data from all park projects should eventually be included in NPSpecies. Furthermore, PriorityDB prevents the proliferation of ad hoc exotic plant lists with unverified source data.

Using PriorityDB, two exotic plant watch lists are generated for each park. The “early detection watch list” consists of high priority exotic plants that occur in the state (based on USDA Plants), but are not known to occur on the park (based on NPSpecies). The second list, referred to as the “park-established watch list”, is a list of high priority exotic plants documented in NPSpecies as occurring in the park. As their names suggest, these two lists are developed to detect new invasions and monitor established plant invasions, respectively.

A vulnerability of PriorityDB is that the USDA Plants and NPSpecies databases may contain mistakes or omissions. For example, USDA Plants may not report a plant as occurring in a state where a manager knows the plant to occur. Alternatively, a manager may identify an exotic plant in the park that has not been documented in NPSpecies. Finally, a resource manager may disagree with the priority designation in PriorityDB. For this reason, a third list, referred to as the “park-based watch list”, allows park managers to request monitoring for additional IEPs. The park-based watch list also allows managers to add IEPs known to occur on lands adjacent to the park. Such plants are important candidates for early detection monitoring. The three lists—the early detection watch list, the park-established watch list, and the park-based watch list—ensure that IEP monitoring is well prioritized on network parks.

While strong arguments can be made that monitoring should focus only on IEPs that will be actively managed in a park, IEP management priorities are likely to shift over time based on spread, resources threatened, and feasibility of control. With these factors in flux, long-term monitoring that focuses on a narrow list of species of immediate concern may fail to provide critical information on IEP distribution and abundance. On the other hand, while more detailed prioritization is possible, this basic approach eliminates the need for more exhaustive, time-consuming, and often redundant assessments of each exotic plant species. As other organizations prioritize exotic plants based on life-history and management feasibility, PriorityDB will incorporate this information. As the lists are updated to include the most current rankings, new species will be added to the list and some species may be removed. Managers should be aware, however, that these lists are inevitably imperfect, requiring managers or volunteers to watch for other unlisted IEPs during routine management activities.

2b. Rationale for selecting this sampling design over others

Taking a holistic approach to IEP management, national park managers work to prevent the introduction of IEPs (usually via propagules), detect and respond rapidly to new IEP invasions, and control or at least contain established invasions. The probability of successful control decreases at each stage on this invasion continuum (Naylor 2000, McNeely 2001). Early detection and rapid response generally require far fewer resources than managing established IEP populations (OTA 1993). Eradication efforts are most successful for invasions less than 2.5 acre (1 ha) and typically not successful for invasions exceeding 250 acres (100 ha) (Rejmanek and Pitcairn 2002). While early detection usually implies the establishment of plants not previously

occurring on the park, the scale should clearly be specified. For example, early detection in previously non-infested sections of a national park may also warrant immediate control at a more localized scale.

A three-stage approach applies to the management of IEPs regardless of invasion status: inventory/survey, monitoring, and management (Rew et al. 2006). Inventories document the presence and, in some instances, the abundance or extent of IEPs in a natural area. Monitoring, on the other hand, provides unbiased, statistically powerful, and cost effective approaches to detect change in IEP abundance or distribution (Gibbs 1998). At the risk of oversimplification, inventories often focus on extensive spatial scales, while monitoring focuses only as broadly as necessary to provide reasonably precise variable estimation given the expected spatiotemporal variability. The line between inventory and monitoring begins to blur if the inventory is designed to be repeated over time and to allow detection of changes in IEP abundance or distribution.

A perfect map of IEPs on a national park would fully meet most basic inventory and monitoring needs. As an inventory product, maps comprehensively identify and locate IEPs, allowing natural areas managers to assess the scope of the problem, strategically plan management, and prescribe actions for exact locations. From a monitoring standpoint, maps with reasonably small minimum mapping units reproduced accurately over time would clearly detect changes in the abundance and spread of IEPs. Combined with information on the treatments applied to IEPs, maps could also assess management effectiveness. Wide-spread interest in weed mapping reflects the potential benefit of such maps and the availability of GPS technology. Numerous weed mapping efforts have been initiated in many countries and by local, state, federal, and non-governmental agencies in the United States. The North American Weed Management Association (NAWMA) has issued guidelines to bring a minimum level of standardization to mapping efforts in North America (NAWMA 2002).

Despite numerous advantages, comprehensive mapping of IEPs in national parks faces several challenges. In order to accurately track change using mapped perimeters, replicable mapping rules must be carefully observed. For example, a minimum mapping unit must be designated and followed. Mapping using small minimum units can often only be accomplished over small areas. As map unit size increases, mapping becomes more efficient, but increases the difficulty of detecting change in infestation perimeters and introduces more error in estimates of their abundance within the perimeter. Furthermore, comprehensively mapping IEPs on a large landscape, even using large map units, is generally cost-prohibitive.

Given the limitations of mapping, a few alternatives are available: 1) develop statistically rigorous measures of IEP cover and frequency (Elzinga et al. 2001), 2) limit mapping or sampling to suitable habitat or likely points of invasion (Despain et al. 2001, Poon and Margules 2004, Rew et al. 2006), 3) combine sampling with a landscape modeling approach to determine likelihood of occurrence (Chong et al. 2001, Campell et al. 2002, Shafii et al. 2003, Rew et al. 2005, Chong et al. 2006, Barnett et al. 2007), and 4) map changes in IEP distribution and abundance using remotely sensed imagery (Anderson et al. 1996, Everitt et al. 1996, Lass et al. 1996, Lass et al. 2002, Lawrence et al. 2006). The strengths and weaknesses of each approach should be evaluated relative to the monitoring objectives.

1. A precise measurement of IEP cover or frequency would provide a strong indicator of spread over time. However, the spatiotemporal variability in IEP populations, especially small populations, may preclude precise and powerful estimation. Additionally, a lack of spatial referencing prevents managers from determining if the plant may impact areas that protect particularly valuable resources.
2. Targeting monitoring to invasion pathways or suitable habitat may greatly increase sampling efficiency and the precision of abundance and frequency estimates. However, this approach depends on the availability of an accurate habitat model. As with all models, sample size and methods affect model accuracy. Given the tendency of IEPs to expand their range, even accurate maps may not reflect the invasion potential of a plant. The need to monitor multiple IEP species simultaneously can also diminish the practicality of this approach.
3. Combined with spatially referenced habitat data, sampling may be used to map the probability of IEP occurrences on the landscape. These maps show a generalized area where the species may be located and can estimate the percentage of potential habitat occupied. In this regard, the maps can provide a powerful assessment tool for management planning and for improving search or sampling efficiency (see #2). Once management decisions are made, managers must still survey high probability areas for exact IEP locations. Limited data can compromise the reliability of these habitat maps since small invasions provide little site-based habitat information, requiring extrapolation from other invaded sites or from the native range. The ability of such designs to determine change in IEP abundance or frequency may suffer from the same problems mentioned above (see #1).
4. Successful identification of IEPs from remotely sensed imagery offers the potential to track changes in distribution and abundance over extremely large areas. This has been accomplished for a number of species in rangelands where interference from tree canopies is limited. Developing reliable reflectance signatures for IEPs may depend on distinct phenological or habitat characteristics, as well as relatively large patch sizes (Young and Schrader 2007). Signatures can only feasibly be developed for a relatively small number of species.

Given these mapping, sampling, and modeling challenges, the sampling design for this protocol was selected to balance multiple objectives. These objectives include: identifying high priority invasive exotic plants, focusing on natural and restored areas, ensuring good spatial coverage, detecting new plant invasions, monitoring multiple species simultaneously, tracking changes in abundance and distribution of existing invasions, and addressing management priorities, while working within program capacity. The protocol emphasizes the quick collection of IEP location and abundance data to maximize the area searched. Maximizing the search area provides the greatest opportunity to find new invasions in parks, while also maximizing encounter of established IEPs. For small parks (reference frame <350 acres/142 ha), a relatively high percentage of the ground is covered to create a map of the plant locations on the park. For large parks (reference frame $\geq$ 350 acres/142 ha), the method covers a greater portion of the park than is typically covered using plot-based sampling approaches. At the same time, the sampling units (search units or line transects) are semi-permanent, which should reduce sample variance to

improve detection of change in IEP abundance and distribution over time. By default, absence data (i.e., negative data) are collected as IEP search routes are known. The flexibility to observe areas at some distance from established belt transects also allows surveyors to detect additional IEPs. Taken together, the maps and estimates of cover and frequency provide critical information for designing IEP control strategies.

Prior to adopting this monitoring protocol, we also assessed its weaknesses. As with any sampling or mapping approach, plants may be overlooked due, first and foremost, to incomplete coverage of the sample area, as well as differences in observer's taxonomic expertise and plant detectability due to growth-form or surrounding vegetation. Changes in the distribution (i.e., frequency) of IEPs must be interpreted with this in mind. Substantial interobserver error associated with visual cover class estimates applied at such a broad scale will also reduce resolution to detect change in cover over time. Because locations are not documented precisely, the amenability of these data to spatial analysis is limited. Finally, the design is not necessarily suited to assess the effectiveness of management treatments applied at local scales or to compare the effectiveness of control treatments. For example, a replicated study would be required to determine whether glyphosate or mowing provided more effective treatment of smooth brome (*Bromus inermis*). As the spatial scale of control increases with cumulative management actions, however, assessment of management effectiveness becomes increasingly feasible with this design.

2c. Site selection

The reference frames directing monitoring were designed to focus on accessible natural and restored areas. Areas requiring special equipment for access were excluded from the reference frame. In some cases, reference frames were much smaller than the park acreage. For example, much of the acreage at ARPO was flooded following downstream construction of a dam. The decision to focus on natural and restored areas was based on the following reasons. First, because managers are generally aware that disturbed areas support numerous weeds, we determined that the limited resources available for monitoring would be best allocated towards intact natural areas. Second, some IEPs are well established on network parks, but do not show a propensity to invade intact natural areas, particularly forests. Early detection in these natural areas ensures a rapid response as needed, while taking a wait-and-see approach in the extensively invaded areas where successful control is unlikely (e.g., battlefields). Third, IEPs are established (and presumably establish) throughout natural areas on network parks, possibly due to the disturbance history or relatively small size of many Heartland Network parks. Finally, as a logistical consideration, some highly disturbed areas in the network, especially early successional forests, are virtually impenetrable. The reference frame for each park was created in a GIS to define the area of interest (i.e., statistical population). Reference frames were developed following field reconnaissance, consultation with park resource managers, and review of vegetation maps and remotely sensed images. Details on reference frame design and sample selection for each park are presented in Appendix B.

2d. Sampling frequency and replication

The long-term goal is to monitor IEPs in each park on five-year basis with two exceptions. CUVA, due to its large size, will be monitored completely in 2007 and, beginning in 2010, annually by staff stationed at the park. Monitoring at EFMO will be partitioned over two years

between uplands and bottomlands. In an effort to expedite invasive exotic plant monitoring, however, a contractor was hired to monitor seven parks (ARPO, GWCA, HOME, LIBO, PERI, TAPR, and WICR) in 2006. Network staff also conducted exotic plant monitoring at PIPE and HEHO in 2006. Because of this intensive initial effort, the next round of sampling will be implemented at LIBO and WICR on a three-year interval, at ARPO, HOME, and PIPE on a four-year return interval, and at EFMO and TAPR on a six-year interval. Thereafter, the five-year revisit schedule will be implemented (Table 2).

Table 2: Revisit schedule for exotic plant monitoring.

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
ARPO	X				X					X		
CUVA		X			X	X	X	X	X	X	X	X
EFMO	X						X	X				X
GWCA	X					X					X	
HEHO	X					X					X	
HOCU			X					X				
HOME	X				X					X		
HOSP			X					X				
LIBO	X			X					X			
PERI	X					X					X	
PIPE	X				X					X		
TAPR	X						X					X
WICR	X			X					X			

2e. Recommended number of sampling sites

Two types of sampling units were developed for parks of different sizes: 1) exotic plant search units for small parks (reference frame <350 acres/142 ha) and 2) line transects on large parks with high to moderate accessibility (reference frame $\geq$ 350 acres/142 ha). Small parks include ARPO, GWCA, HEHO, HOCU, HOME, LIBO, and PIPE. Large parks include CUVA, EFMO, HOSP, PERI, TAPR, and WICR. Exotic plant search units were created by dividing park management units into search units that were generally 1 (0.4 ha) to 3 acres (1.2 ha) in size with 2 acres as the target size (see Appendix 1 for examples). For large parks (reference frame >350 acres/142 ha), systematically located line transects were established in a GIS using a random start (see Appendix 1 for examples). This process created contiguous line transects across the entire park, which increases sampling efficiency. The length of line transects as well as the distance between the lines of contiguous transects is 200 m on EFMO and WICR and 400 m on CUVA, HOSP, PERI, and TAPR. The number of sampling sites is shown in Tables 3 and 4 for small and large parks, respectively. The number of person days required to complete sampling is also estimated.

2f. Timing of sampling

In general, IEPs at a particular park will be monitored at the same time of year. Consistency in timing should maintain consistency in detection probabilities and cover estimates for most species. For many species, sampling any time during June-September is not expected to drastically alter monitoring results. However, sampling after May could prevent detection or

identification of spring blooming exotic plants such as dame's rocket (*Hesperis matronalis*), plants in the families *Brassicaceae* and *Caryophyllaceae*, and exotic cool season grasses such as Kentucky bluegrass (*Poa pratensis*), brome grasses (*Bromus* spp), and fescues (*Lolium* spp). The semi-evergreen nature of some species, such as *Lonicera japonica*, allows IEP monitoring to continue through autumn. Garlic mustard (*Alliaria petiolata*) may only be effectively detected prior to leaf-out or following leaf-fall.

2g. Levels of change that can be detected for the amount/type of sampling being instituted

Differences in search effort, plant detection probabilities, and GPS error associated with navigation pose several problems for analyzing changes in IEP abundance and distribution. The coarse scale of cover measurement and the difficulty in ocularly integrating cover across large areas may contribute to substantial interobserver differences. However, the use of semi-permanent search units and line transects should partially reduce sample variance. Using non-overlapping cover ranges as the criteria for detecting change in IEP abundance on six smaller parks, IEPs of low abundance could have to increase over five doubling periods, while IEPs of high abundance could have to increase over three or four doubling periods before a change in abundance would be detected (Appendix A).

Table 3: Overview of exotic plant search units on small parks (reference frame <350 acres/142 ha)

Park	Reference Frame Acres (ha)	Number of Exotic Plant Search Units	Estimated Person-Days
ARPO	339 (137)	169	15
GWCA	188 (76)	97	9
HEHO	82 (33)	50	6
HOCU	223 (90)	107	12
HOME	168 (68)	82	9
LIBO	153 (62)	76	9
PIPE	278 (113)	114	12

* = Due to ongoing restoration, number of exotic plant search units is not known.

Table 4: Overview of line transects for large parks (reference frame >350 acres/142 ha)

	Reference Frame Acres (ha)	Number of Line Transects	Transect Miles (km)	Estimated Person-Days
CUVA (400 m)	26,241 (10,619)	822	161.6 (260.1)	60
EFMO (200 m)	2,305 (933)	272	30.5 (49.1)	16
PERI (400 m)	3,124 (1,264)	102	22.5 (36.2)	12
TAPR (400 m)	10,735 (4,344)	301	71.5 (115.1)	20
WICR (200 m)	1,350 (546)	171	17.0 (27.4)	9

* = Reference frame development still in progress.

3. Field Methods

3a. Field season preparations and equipment set-up

Sampling trips shall be scheduled and organized prior to the start of each field season. Prior to working in the field, observers must review the network safety plan and the entire protocol. Observers will review IEP identification using herbarium specimens, keys, and photographs. The crew leader will provide a refresher on plant identification, GPS navigation, compass use, and foliar cover estimation. All equipment and supplies, especially GPS units, should be organized and prepared for the field season. All files needed for navigation will be loaded onto a GPS unit and a laptop for transport to the park.

3b. Sequence of events during field season

Prior to visiting the field sites, the park natural resource manager and superintendent will be contacted. All equipment required for sampling is assembled and checked (SOP 3).

Each day the crew leader provides a briefing regarding safety, plant identification, and park navigation. All observers must be properly trained (SOP 3). The crew leader assigns crew members to the search units or line transects for the day. Prior to beginning work in the field, observers collectively estimate IEP cover over a given area and compare observations in order to calibrate cover class estimates.

For small parks, surveyors make three equidistant passes through each search unit in an east-west direction, focusing on an approximately 3- to 12-m wide belt transect, and estimate the cover of each IEP encountered using the following cover scale: 0=0, 1=0.1-0.9 m², 2=1-9.9 m², 3=10-49.9 m², 4= 50-99.9 m², 5=100-499.9 m², 6= 499.9-999.9 m², 7=1,000-4,999.9 m², 8=5,000-9,999.9 m², and 9=10,000-14,999.9 m² (SOP 5). Observations are made in the widest possible belt given site conditions. Line transects are followed using GPS navigation (SOP 2 and 5). Assuming a perfectly square 2-acre plot (0.8 ha), surveyors cover approximately 10 to 40 % of the park reference frame. The time required to complete monitoring depends on park size and access logistics.

For large parks, surveyors record and estimate the cover of each IEP encountered in an approximately 3- to 12-m belt transects using the following cover scale: 0=0, 1=0.1-0.9 m², 2=1-9.9 m², 3=10-49.9 m², 4= 50-99.9 m², 5=100-499.9 m², 6= 499.9-999.9 m², 7=1,000-4,999.9 m², 8=5,000-9,999.9 m², and 9=10,000-14,999.9 m² (SOP 5). Observations are made in the widest possible belt given site conditions. Line transects are followed using GPS navigation (SOP 2 and 5). Assuming that surveyors estimate plant cover in a 12-m belt, 1.5 to 6 % and 0.75 to 3 % of the park reference frame will be surveyed using 200 m and 400 m transects, respectively. The time required to complete monitoring depends on park size and access logistics.

Surveyors also have discretion to search areas beyond the belt transects to target locations likely to support exotic plants (e.g., field edges, roads). If surveyors search areas beyond the 12-m wide belt, the search unit number or polygon number (for line transects) and a cover class are assigned to that IEP species (SOP 5).

3c. Details of taking measurements with example field forms

Measurements require the use of a foliar cover class scale. Foliar cover is the area of ground covered by the vertical projection of the leaf surface area of the plants. An example field form is presented in Table 5.

Table 5: Exotic Plant Monitoring Data Sheet

Observer: Craig Young

Park: ARPO

Date: 6/20/2006

Exotic Plant Search Unit/Line Transect #: search unit 22

Exotic Plant Species	Cover in Belt	Cover out of Belt	Exotic Plant Species	Cover in Belt	Cover out of Belt
<i>Lonicera japonica</i>	3	2			
<i>Spiraea prunifolia</i>	2	-			
<i>Ligustrum vulgare</i>	4	-			

Cover class scale: 0=0, 1=0.1-0.9 m², 2=1-9.9 m², 3=10-49.9 m², 4= 50-99.9 m², 5=100-499.9 m², 6= 499.9-999.9 m², 7=1,000-4,999.9 m², 8=5,000-9,999.9 m², and 9=10,000-14,999.9 m²

Access note : _____

3d. Post-collection processing of samples

Research specimens may be collected to confirm identification of IEPs, especially those that are likely to be identified incorrectly (SOP 5). In some cases, small or partial samples may be quickly collected and stored in a field notebook. Location, description, and habitat information are recorded using an unknown specimen data sheet. Research specimens are only for confirmation of taxonomy and will not be stored in a collection. Alternatively, photographs may also be used to document unknown specimens.

4. Data Handling, Analysis, and Reporting

4a. Metadata procedures

Metadata will be generated using ESRI ArcGIS metadata tools (SOP 6). The generated metadata file will be stored in XML format and uploaded to the WASO NPS metadata and GIS data store. The federally threatened status of the Missouri bladderpod requires that information access is restricted to NPS personnel, regulating agencies, or, with permission, NPS partners.

4b. Overview of database design

The IEP monitoring protocol requires two databases: 1) an invasive exotic plant prioritization database (PriorityDB) (SOP 1) and 2) an invasive exotic plant information geodatabase (LocationDB) (SOP 6). PriorityDB contains information for known and potential IEPs of

network parks. LocationDB maintains spatially referenced IEP abundance data and ancillary tables.

4c. Data entry, verification, and editing

Data processing typically involves the following steps: data entry, data verification, data validation, and backups/storage (see SOP 6). Data entry consists of transferring data from field sheets into a database using a data entry interface. Data verification immediately follows data entry and involves checking the accuracy of computerized records against the original source. Validation procedures seek to identify generic errors (e.g., missing, mismatched, or duplicate records) as well as logical errors specific to particular projects.

4d. Recommendations for routine data summaries and statistical analyses to detect change

Most routine data summaries will focus on reporting the locations and cover of species during the most recent survey and the amount of change since the previous survey (usually 5 years before). Our main objectives are to provide managers with the information needed to potentially eradicate new invasions and control existing invasions, while providing feedback for ongoing control efforts.

4e. Recommended reporting schedule

Reports will be prepared and distributed by May of the next calendar year following data collection (SOP 8).

4f. Recommended reporting format with examples of summary tables and figures

The report will follow the standard format required in the CBE Style Manual (1994) (SOP 8). The natural resource technical report template for NPS documents is also required (<http://www.nature.nps.gov/publications/NRPM/index.cfm>). An example report for Homestead National Monument of America is available at http://science.nature.nps.gov/im/units/htln/library/monitoring/reports/HOME_IEP_2006.pdf.

4g. Recommended methods for long-term trend analyses

A control chart approach could be used to set thresholds related to management actions (Morrison 2008). Regression analyses could be employed to estimate rates of change or the trajectory of change (i.e., linear or nonlinear). A repeated measures ANOVA could also be used. Because most parks will only be sampled every five years, however, statistical analyses in which sample size is equivalent to number of years (e.g., regression) should only be done after enough data points are obtained to allow sufficient statistical power.

A complicating issue with such classical statistical analyses is that managers may act to reduce the densities of a number of the invasive species. These actions are likely to vary both spatially and temporally within parks and among parks. Unless the histories of such management actions

are documented and made available to the analyst, interpretation of observed long-term patterns may prove difficult.

4h. Data archival procedures

Frequent backups are critical for preventing data loss. Full backup copies of the monitoring project will be stored at an off-site location. Additional digital copies will be forwarded to the NPS (WASO) NR-GIS Data Store, NatureBib, and NPSSpecies Database Systems.

5. Personnel Requirements and Training

5a. Roles and responsibilities

The network botanist serves as the project manager and normally as the crew leader for IEP monitoring. The network coordinator supervises the botanist. Data management is the shared responsibility of the project manager and the data manager. Typically, the project manager oversees data collection, data entry, data verification and validation, as well as data summary, analysis, and reporting. The data manager designs the database and oversees data security, archiving, and dissemination. The data manager, in collaboration with the project manager, also develops data entry forms and other database features to assure data quality and to automate report generation. The data manager is responsible for building adequate QA-QC procedures into the database management system and for following appropriate data handling procedures.

5b. Qualifications

A competent, detail-oriented observer is essential for collecting credible, high-quality IEP data. Misidentification of species decreases capacity to detect trends in IEP abundance and distribution through time. Field observers must be able to accurately identify target IEPs. Field observers must also be skilled with GPS navigation and data collection. Observers should be well-organized, work well as a team member, be comfortable in the field, and work methodically under difficult conditions.

5c. Training procedures

Training is essential for developing competent observers (see SOP 1). Observers will review exotic plant identification using herbarium specimens, keys, and photographs. The crew leader will provide a refresher on exotic plant identification, GPS navigation, compass use, and foliar cover estimation. Observers will be tested frequently on their ability to identify exotic plant species.

6. Operational Requirements

6a. Annual workload

Monitoring will require a three-person crew each year. Depending on the year, 45 to 70 person-days will be required annually to complete monitoring. The number of person-days may change depending on the parks sampled, logistics, weather, and crew skill level.

6b. Facility and equipment needs

Vegetation monitoring requires herbarium storage, taxonomic guides, hand lenses, microscopes, a digital camera, GPS units, and compasses.

6c. Startup costs and budget considerations

Personnel expenses for field work are based on a crew of three people during a 60-day season: botanist, a biologist or botanist, and a biologist or seasonal biological technician (Table 6). Reports are produced collaboratively by the project manager, quantitative ecologist, data manager or GIS specialist, and the network coordinator. Data management expenses include staff time of biological science technicians, project manager, and data management staff. Equipment costs include five-year annualized equipment and projected vehicle costs.

Table 6. Estimated startup costs and annual budget for Heartland Newtork Inventory and Monitoring Program invasive exotic plant monitoring.

Category	Cost
Equipment Costs (5-yr annualized)	\$14,750
Salary (field and office)	\$54,750
Travel Costs	\$6,750
Annual Equipment-Supplies	\$500
Administrative Support and Overhead	\$4,000
TOTAL	\$80,750

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Appendix A: Vegetation Description and Overview of Invasive Exotic Plants on Network Parks

Eastern Deciduous Forest

The vegetation in the Eastern deciduous forest parks differs dramatically across parks, requiring independent descriptions for each park.

Effigy Mounds National Monument

The oak-hickory forests at Effigy Mounds National Monument (EFMO) occur on extremely rugged terrain along Mississippi River bluffs. At the risk of oversimplification, the EFMO uplands support three general forest community types: a sugar maple (*Acer saccharum*)-basswood (*Tilia americana*) forest on dry-mesic to mesic slopes and ravines, oak-hickory forest on drier sites, and chinquapin oak (*Quercus muehlenbergii*) woodlands with goat prairies on bluff tops and severe slopes (Hop, Lubinski, and Menard 2005). While the majority of the forests were logged, stands at EFMO reflect different degrees of “naturalness” based on land-use in the last 50 years. In the past 10 years, resource managers at EFMO restored prairie on a number of old fields. These tallgrass prairies share many characteristics with the restored prairies in the Ozark plateau and tallgrass prairie parks. Forested and herbaceous wetlands occur along a gradient of increasing inundation along backwater sloughs, streams, and rivers.

A relatively small number of plants at EFMO pose wide-scale resource management challenges. Garlic mustard (*Alliaria petiolata*) occurs extensively throughout the maple-basswood and oak-hickory forests. Multiflora rose (*Rosa multiflora*), Japanese honeysuckle (*Lonicera japonica*), Japanese barberry (*Berberis thunbergii*), and buckthorn (*Rhamnus cathartica*) also occur throughout the forests. The goat prairies are relatively unaffected by exotic plants, although white sweet clover (*Melilotus alba*), cheat grass (*Bromus tectorum*), and Morrow’s honeysuckle (*Lonicera morrowii*) have been found in low numbers. Network staff observed a low density of sericea lespedeza (*Lespedeza cuneata*) and cheat grass (*Bromus inermis*) in the restored tallgrass prairie in 2005. Reed canary grass (*Phalaris arundinacea*) and purple loosestrife (*Lythrum salicaria*) have invaded herbaceous wetlands at EFMO.

Cuyahoga Valley National Park

Cuyahoga Valley National Park (CUVA) encompasses a mosaic of natural vegetation types interspersed with developed land uses. Located in the glaciated Allegheny Plateau of northeastern Ohio, natural vegetation of the park is comprised of 80% mixed-mesophytic forest (Braun 1961), predominantly of oak-hickory associations, but also including maple-oak, oak-beech-maple, maple-sycamore, pine-spruce, and hemlock-beech associations. The long history of intensive land use has left the park with forests possessing vast differences in age and community structure. Nearly 20% of the species found in CUVA are exotic. The high number of exotic plant species is probably due to the disturbance history of the park. While there are many exotic species, less than ten are considered to be highly invasive. Garlic mustard, Japanese honeysuckle, multiflora rose, glossy buckthorn (*Rhamnus frangula*) and Asian bush honeysuckles (*Lonicera maackii*, *Lonicera morrowii*, and *Lonicera tatarica*) inhabit many of the

forests (Vorac 2003). Interspersed among these forests are successional old fields (approximately 6%), wet meadows, and other wetland habitats (approximately 5%). Aggressive wetland plants at CUVA include purple loosestrife, common reed (*Phragmites australis*), Japanese knotweed (*Polygonum cuspidatum*), and reed canary grass (Vorac 2003).

Hopewell Culture National Monument

Lands at Hopewell Culture National Monument (HOCU) have been clearcut and cultivated. Current management includes active and passive prairie restoration. While oak-hickory forests covered HOCU prior to European settlement, cultural resource protection necessitates management for grasslands. To date, approximately 14 acres (6 ha) have been planted with shallow rooted prairie natives. The successional fields include a number of exotic plants such as musk thistle (*Carduus nutans*), Canada thistle (*Cirsium arvense*), and bull thistle (*Cirsium vulgare*). Johnson grass (*Sorghum halepense*) has invaded recently restored sites.

Lincoln Boyhood National Monument

Based on General Land Office notes and field investigations, the forests at Lincoln Boyhood National Monument (LIBO) consisted of upland hardwood forest, mesic mixed hardwood forest, and bottomland forest along a decreasing elevation-soil moisture gradient (Pavlovic and White 1989). With the exception of a small patch of forest with old trees, the vegetation on upland sites was largely cleared prior to NPS acquisition. Currently, lowland and upland old fields consist of a brushy cover of saplings, shrubs, and vines. Former home sites support maples, elms (*Fraxinus* spp.), and ornamental trees, as well as numerous exotic pasture grasses such as fescue (*Lolium arundinaceum*), orchard grass (*Dactylis glomerata*), and bluegrass (*Poa pratensis*). The bottomlands consist largely of seral forests with an overstory of sweetgum (*Liquidambar styraciflua*) and red maple (*Acer rubrum*). Pin oak (*Quercus palustris*) dominates the remnant mature bottomland forests. A mixed maple-tulip tree (*Liriodendron tulipifera*) forest, planted during the 1920s and 1930s, covers much of the southeastern section of the park. Other uplands have not been planted, but have succeeded to tulip tree, red maple, sweetgum, and sassafras (*Sassafras albidum*). The patch of mature forest contains a canopy of red oak (*Quercus rubra*), black oak (*Quercus velutina*), and white oak (*Quercus alba*), as well as pignut hickory (*Carya glabra*) and shagbark hickory (*Carya ovata*). Japanese honeysuckle occurs extensively in all forests at LIBO with the exception of the mature oak-hickory forest (Pavlovic and White 1989, Williams 2003). Multiflora rose, privet (*Ligustrum* spp.), and periwinkle also occur extensively in the forests (Williams 2003). Sericea lespedeza, forsythia (*Forsythia* sp.), Chinese yam (*Dioscorea oppositifolia*), Japanese knotweed, and English ivy (*Hedera helix*) exist in isolated populations.

Mississippi Embayment

The forests at Arkansas Post National Memorial (ARPO), although highly disturbed, are typical of Mississippi Delta alluvial floodplains with inundation period strongly influencing plant community composition. Upland species, such as white oak, red oak, blackjack oak (*Quercus marilandica*), swamp chestnut oak (*Quercus michauxii*), post oak (*Quercus stellata*), and mockernut hickory (*Carya alba*) are found on well-drained soils (Irving and Brennholts 1977). Seral communities of cherrybark oak (*Quercus pagodaefolia*), water oak (*Quercus nigra*), sweetgum, Eastern red cedar (*Juniperus virginiana*), and loblolly pine (*Pinus taeda*) are found

on moderately well drained sites. Flooded sites at ARPO support forests of water oak (*Quercus nigra*), willow oak (*Quercus phellos*), overcup oak (*Quercus lyrata*), water hickory (*Carya aquatica*), pecan (*Carya illinoensis*), Carolina ash (*Fraxinus caroliniana*), sugarberry (*Celtis laevigata*), and cypress (*Taxodium distichum*). Vines are abundant in the swamps and bottomlands. ARPO may have historically included now extirpated patches of tallgrass prairie at the southern terminus of the Grand Prairie, a 1,500 square mile outlying prairie region (Irving and Brennholts 1977). Trifoliate orange (*Poncirus trifoliata*), common privet (*Ligustrum vulgare*), Chinese privet (*Ligustrum sinense*), and Japanese honeysuckle have invaded forests, while Canada thistle occurs in disturbed fields at ARPO.

Ozark Plateau

The old fields and successional forests of the Ozark plateau reflect the legacy of land disturbance, including logging and cultivation. In 1940, a linear band of trees remained along streams, while forested vegetation was largely absent from the lands that became George Washington Carver National Monument (GWCA) and Wilson's Creek National Battlefield (WICR). On land that became Pea Ridge National Military Park (PERI), relatively intact forest remained on the steeper slopes, while fields covered less rugged sites. The mature oak-hickory forests included a post oak (*Quercus stellata*)-blackjack oak (*Quercus marilandica*) type, white oak type, black oak type, and a mixed oak-hickory type (Dale 1983). Small sections of wooded streams also remained on the park. Numerous old fields have succeeded to Eastern red cedar forest and mixed hardwood forest. At GWCA and WICR, restored prairies mimic the small-patch grasslands that were mixed among the woodlands in the Eastern deciduous forest-prairie border. Sericea lespedeza, Johnson grass, sweet clovers (*Melilotus* spp.), fescue, Kentucky bluegrass, bull thistle, and musk thistle are found in the old fields and restored prairies. Typical exotic plants in the woodlands and forests include black locust (*Robinia pseudoacacia*), Osage orange (*Maclura pomifera*), Japanese honeysuckle, and multiflora rose. Nepalese browntop (*Microstegium vimineum*) has colonized wet, forested sites at PERI. *Bromus tectorum*, *Bromus inermis*, and annual bromes have invaded glades at WICR that support the federally threatened Missouri bladderpod (*Lesquerella filiformis*).

Tallgrass Prairie

Three of the four tallgrass prairie parks (Herbert Hoover National Historic Site-HEHO, Homestead National Monument of America-HOME, and Pipestone National Monument-PIPE) are relatively small in size and include restored prairies, while Tallgrass Prairie National Preserve (TAPR) protects over 10,000 acres (4,047 ha) of uncultivated, working rangeland. HOME features the second oldest restored prairie in the United States. PIPE includes a small section of virgin prairie that supports the western prairie fringed orchid (*Platanthera praeclara*). Several common invaders in these prairies include: Kentucky bluegrass, smooth brome, and sweet clover (*Melilotus officianalis*). Reed canary grass and crown vetch (*Securigera varia*) also occur extensively at HEHO and PIPE. Common buckthorn occurs in the woodlands along Sioux quartzite outcrops at PIPE. Managers at PIPE also identified a small leafy spurge (*Euphorbia esula*) infestation. At HOME, white mulberry (*Morus alba*), reed canary grass, and garlic mustard may become problematic in the mesic bur oak (*Quercus macrocarpa*) forest (Mlekush and DeBacker 2003). TAPR, in the Flint Hills of Kansas, has several scattered infestations of

sericea lespedeza, but no known serious infestations outside of the smooth brome-dominated pasture that is currently being restored. Caucasian bluestem (*Bothriochloa bladhii*), historically planted to stabilize soil, is found on dams, roads, and streambanks. Kentucky and annual bluegrass occur throughout the prairie.

Appendix B: Reference Frame Development and Sample Selection Procedures

Sample selection details for each park in which invasive exotic plant (IEP) monitoring will be conducted are presented below. For some parks, park boundaries and management unit boundaries were used in the reference frame or sample selection process. For these boundaries developed by the NPS Midwest Region, the shapefiles are available on the network server. Should these boundaries be modified, the older versions used for reference frame development and sample selection will continue to be available on the network server. All other GIS layers used or developed, even as intermediate steps during the reference frame development and sample selection process, are located in the exotic plant location geodatabase (see SOP 6) or on the network's geodata drive.

Arkansas Post National Memorial (Figures B.1 and B.2)

Reference frame:

The vegetation at Arkansas Post National Memorial (ARPO), including the main unit and Osotouy unit, consists of developed areas (e.g., roads, visitor's center, picnic area), mowed areas, abandoned agricultural fields, a restored prairie, herbaceous and forested wetlands, and bottomland hardwood forests. The reference frame for ARPO excluded developed areas, mowed lawns, inaccessible herbaceous wetlands, and recently abandoned agricultural areas. The most extensive vegetation type—bottomland hardwood forest—was targeted. In the process, the restored prairie as well as some forested wetland were included in the reference frame. A total of 169 exotic plant search units were developed using a two-acre (0.8 ha) grid as a guide.

Procedures:

1. Following reconnaissance and discussion with Leo Acosta, natural resource manager, reference frames (fcl_arpomainexoticrefframep, fcl_arpoosotouyexoticrefframep) were designed to exclude highly disturbed areas in the two park parcels: the main unit and the Osotouy unit.
2. A two-acre grid (0.8 ha) was created for each parcel (fcl_arpoosotouygrid89p, fcl_arpomaingrid89p) using the NPS AlaskaPak 1.0 extension for ArcMap. The two-acre grid (0.8 ha) was intersected by the reference frame for each parcel. Polygons were then reshaped (e.g., combined, split, etc.) to increase consistency in unit size and search efficiency (fcl_arpoinpp).

Cuyahoga Valley National Park (Figure B.3)

Reference frame: The land within the legislative boundary of Cuyahoga Valley National Park is a complex of differing land ownership and land use patterns. The reference frame was designed to focus on areas that allowed NPS access, were natural in character, or were likely introduction sites for invasive exotic plants. Lands managed by Cleveland Metroparks and Metroparks serving Summit County as well as other local park districts were included. The reference frame excluded active agricultural areas, golf courses, most urban/commercial uses, and open water.

Kevin Skerl and Meg Plona provided local park guidance. The reference frame is 26,241 acres (10,619 ha) with a total of 822 transects. The total transect length is 161.6 miles (260.1 km).

Procedures:

1. Filter using land ownership layer.
 - a. Exclude “private” category (i.e., simple private ownership).
 - b. Exclude “private with scenic easements” category.
 - c. Exclude polygons in “compatible institutional ownership” category, which notably includes Brandywine and Asterhurst golf courses, as well as the Boston Mills and Brandywine ski areas and Dover Lake Water Park. Camps and Blossom Music Center were not excluded. Permission is required to access these properties.
2. Filter agricultural lands using land use (2000/2002) and rural landscape/ agricultural use layers (current as of 2/23/2006).
 - a. Exclude level 1 agricultural lands if the agricultural lands were deemed to be active agriculture based on review by park resource management staff with the following exceptions:
 - i. In some cases, the rural landscape layer more accurately reflected the actual area planned to remain in agriculture. In such case, these shapefiles took priority over the level 1 agricultural areas identified in the land use layer.
 - ii. Areas mowed for the purposes of habitat management were not excluded.
 - iii. In level 1 agricultural lands where resource managers were uncertain of current or planned land management (e.g., agricultural areas on non-NPS lands) the level 1 agricultural lands were excluded.
3. Filter using land use layer (2000/2002)
 - a. Level 3 golf course category was used to exclude Sleepy Hollow and Shawnee Hills golf courses.
 - b. Level 2 ponds, lakes, and reservoirs were used to exclude open water, which included ponds and the inundated wetland areas.
 - c. Urban class level 1 was used to exclude a selected variety of developed land uses, such as buildings, parking lots, mowed lawns, houses, etc.
 - d. The Urban class level 2 subset for communications, transportation and utilities was not excluded to allow rights-of way and road corridors to remain in the reference frame.
4. For field work in 2007, a shapefile will be available to exclude the Krejci Dump CERCLA restoration site from the reference frame.
5. Field workers must be aware that the reference frame includes parcels of continued residential occupancy under life estates or retentions. Permission is required to access these lands. Land owners may be contacted by a phone or a visit. Absent landowner permission, these areas should not be visited for monitoring.

6. The entire reference frame was digitized using the layers described above. During this process, areas where access was restricted (i.e., no access) or cumbersome (i.e., little return for effort expended) were deleted from the reference frame.
7. Randomly selected line transect start- and end-points were then connected with hand-digitized lines (fcl_cuvainplclip). InpID serves as the unique identifier field. InpID 1-534 was digitized at 45°. InpID 535-825 was digitized at 225°.
8. Lines less than 20 m in length were eliminated
9. Wetlands were attributed (0=false, 1=true) using 2005 NAIP imagery and a wetlands layer created by Davey Tree Environmental Consulting.
10. For display purposes, square polygons were created to encompass line transects (fcl_cuvainppclip). The unique identifier InpID allows data to be linked with line transects (fcl_efmoinpl).

Effigy Mounds National Monument (Figure B.4)

Reference frame:

At Effigy Mounds National Monument (EFMO), the reference frame consisted of all areas within the park boundary, which included forests, prairies, herbaceous and forested wetlands, abandoned agricultural land, and developed areas. Developed areas and inaccessible areas (e.g., steep slopes, inaccessible wetlands) will be determined during field reconnaissance. The reference frame may be modified based on those findings. The sample at EFMO consists of 272 200-m line transects.

Procedures:

1. An underlying 50-m grid of points (efmosoilpt) was created to cover EFMO. The grid was originally used for locating vegetation monitoring plots. The 50-m grid resolution was selected as a scale that would accommodate current and future monitoring projects. The grid may or may not have been located using a random start. The grid was oriented at a random unknown azimuth to minimize the influences of built features (e.g. roads, fences) oriented along cardinal directions.
2. The point 12197 in field EFMOGRID6P was randomly selected as the line transect midpoint from which all other midpoints were selected at a 200-m interval. Line transect start-points and end-points were then identified and labeled for each transect. Transect start-, mid-, and end-points were combined in a single file that was clipped to the park boundary (fcl_efmoinpt). InpID serves as the unique identifier field.
3. Line transect start- and end-points were then connected with hand-digitized lines (fcl_efmoinpl). InpID serves as the unique identifier field.

4. For display purposes, square polygons were created to encompass line transects (fcl_efmoinpp). The unique identifier InpID allows data to be linked with line transects (fcl_efmoinpl).

George Washington Carver National Monument (Figure B.5)

Reference frame:

George Washington Carver National Monument (GWCA) consists of developed areas, fescue fields, and restored grasslands. Fescue cover is largely restricted to the newly acquired parcel. At GWCA, the reference frame excluded the developed areas and fescue fields. Nine prairie management units guide management at GWCA. HTLN staff digitized two forested areas, the forests along Carver Branch and Harkins Branch, and redigitized eight of the nine prairie management units to create contiguous polygons. Unit 7A, a very small unit, was merged with the forested unit along Carver Branch. These ten polygons were divided into 97 exotic plant search units.

Procedures:

1. Following reconnaissance, a reference frame (fcl_gwcaexoticrefframep) was designed to exclude the highly disturbed portion of the park in the vicinity of the visitor's center and museum and fescue fields. The reference frame was divided into prairie management units and a single forested unit.
2. A two-acre grid (0.8 ha) was created using the NPS AlaskaPak 1.0 extension for ArcMap (fcl_gwcagrid89mp). Exotic plant search units (fcl_gwcainpp) were created by intersecting the two-acre grid (0.8 ha) with the prairie management units and the forested unit and then reshaping the resulting polygons (e.g., combine, split, etc.) to increase consistency in unit size and search efficiency.

Herbert Hoover National Historic Site (Figure B.6)

Reference frame:

The restored prairie at Herbert Hoover National Historic Site (HEHO) was divided into eight management units. These management units were further divided into 50 exotic plant search units.

Procedures:

1. Following reconnaissance, the reference frame (fcl_hehoexoticrefframep) was designed to encompass the restored prairie at the park. The reference frame was divided to follow the park's prairie management units.
2. A two-acre (0.8 ha) grid, created using the NPS AlaskaPak 1.0 extension for ArcMap, was roughly followed (fcl_hehogrid89mp) to hand digitize exotic plant search units (fcl_hehoinpp).

Homestead National Monument of America (Figure B.7)

Reference frame:

The reference frame at Homestead National Monument of America (HOME) included restored prairie and forest. The area surrounding the school house, the visitor's center, and the site of the new visitor's center were excluded. The fire management units in the prairie and the forested unit were divided into 82 exotic plant search units using a two-acre (0.8 ha) grid as a guide.

Procedures:

1. Following reconnaissance, a reference frame (fcl_homeexoticreframep) was developed, which consisted of the fire management units and a forested unit. This file was created by redigitizing and slightly modifying existing fire management units to ensure contiguity.
2. A two-acre grid (0.8 ha) was created using the NPS AlaskaPak 1.0 extension for ArcMap (fcl_homegrid89mp). Exotic plant search units (fcl_homeinpp) were created by intersecting a two-acre (0.8 ha) grid with the reference frame and then reshaping the resulting polygons (e.g., combine, split, etc.) to increase consistency in unit size and search efficiency.

Hopewell Culture National Historical Park (Figures B.8)

Reference frame:

The Hopewell Culture National Monument (HOCU) reference frame consists of restored prairies and larger forested tracts on the five units that compose the monument. The reference frame, currently consisting of 107 search units, will continue to develop over time as old fields are restored to prairie.

Procedures:

1. Following consultation with natural resource manager Myra Vick, the reference frame (fcl_hocuxoticreframep) was based on hand-digitized forest tracts based on 2004 NAIP imagery and spatially referenced grassland restoration sites.
2. A two-acre grid (0.8 ha) was created using the NPS AlaskaPak 1.0 extension for ArcMap (fcl_hocugrid89mp). Exotic plant search units (fcl_hocuinpp) were created by clipping a two-acre (0.8 ha) grid with the reference frame and then reshaping the resulting polygons (e.g., combine, split, etc.) to increase consistency in unit size and search efficiency.

Lincoln Boyhood Home National Memorial (Figures B.9)

Reference frame:

The land cover at Lincoln Boyhood National Memorial (LIBO) consists of developed areas, a working farm, and forest. The forests demonstrate a legacy of land clearing, old field succession, and reforestation by the Civilian Conservation Corps. The reference frame strata were selected to reflect park management priorities. A classification scheme of four priority categories was developed. Category 1 areas included forest with large diameter oaks. Category

2 areas included forests surrounding the category 1 tract that were likely planted during the 1930s or 1940s. Category 3 areas included a matrix of approximately 30 to 40 year-old successional forest. Category 4 areas included developed areas and fescue fields and were not included in the reference frame.

Procedures:

1. Following field reconnaissance and consultation of the document “[Forest Restoration of Lincoln Boyhood National Memorial: Presettlement, Existing Vegetation, and Restoration Management Recommendations](#)” by Pavlovic and White (1989), a reference frame (fcl_liboexoticreframep) was designed to exclude the highly disturbed portions of the park and to delineate a patch including old-growth trees.
2. A two-acre (0.8 ha) grid was created using the NPS AlaskaPak 1.0 extension for ArcMap (fcl_libogrid89mp). Exotic plant search units (fcl_liboinpp) were created by intersecting a two-acre (0.8 ha) grid with the reference frame and then reshaping the resulting polygons (e.g., combine, split, etc.) to increase consistency in unit size and search efficiency.

Pea Ridge National Military Park (Figures B.10)

Reference frame:

For Pea Ridge National Military Park (PERI), a reference frame was developed that focused on high quality natural areas. The reference frame eliminated mowed fields, such as the large fescue-dominated battlefield, and recently disturbed areas. The determination was made following reconnaissance, discussion with Kevin Eads (natural resource manager), and interpretation of aerial photographs. The sample consists of 125 400-m line transects.

Procedures:

1. An underlying 50-m grid (fcl_perigrd50mt) was created to encompass the PERI boundary using the NPS AlaskaPak 1.0 extension for ArcMap. The 50-m grid resolution was selected as a scale that would accommodate current and future monitoring projects. The grid was located using a random start. The grid was oriented at 45° to minimize the influences of built features (e.g. roads, fences) oriented along cardinal directions. Points were located at grid vertices (fcl_perigrd50mt) using “data management tools” in the “ArcToolbox” found in ESRI ArcMap 9.0.
2. The points (fcl_perigrd50mt) were clipped (fcl_perigrd50mClipt) using the PERI boundary (see peribndp).
3. The midpoint of the first line transect was selected from the available points (see fcl_perigrd50mClipt) by randomly selecting a point (PeriGrdID 31035) to serve as a transect midpoint. Using this point as an anchor, points were selected at 400 m intervals in upward, downward, and lateral directions (i.e., no diagonals).

4. Line transect start- and end-points were then identified in lateral directions at 200 m from the line transect midpoints. Transect start-, mid-, and end-points were combined in a single file (fcl_periinpt).
5. Line transect start- and end-points were connected with hand-digitized lines (fcl_periinpl). InpID serves as the unique identifier field.
6. Points (fcl_periinp_clipt) and line transects (fcl_periinp_clipl) were then clipped to the reference frame (fcl_periexoticreframe).
7. The line transects were identified by the same primary key (InpID) as the line transect midpoints.
8. For display purposes, square polygons were created to encompass line transects (fcl_periinpp). InpID serves as the unique identifier field.

Pipestone National Monument (Figure B.11)

Reference frame:

The land cover at Pipestone National Monument (PIPE) consists of developed areas, virgin prairie, restored prairie, and woodlands. PIPE is divided into thirteen management units. These management units were divided into 117 invasive plant search units using a 2-acre (0.8 ha) grid as a guide.

Procedures:

1. Following reconnaissance a reference frame (fcl_pipeexoticreframe) was designed based on fire management units, while excluding highly disturbed portions of the park.
2. A two-acre (0.8 ha) grid was created using the NPS AlaskaPak 1.0 extension for ArcMap (fcl_pipegrid89mp). Exotic plant search units (fcl_pipeinpp) were created by intersecting a two-acre (0.8 ha) grid with the fire management units and then reshaping the resulting polygons (e.g., combine, split, etc.) to increase consistency in unit size and search efficiency.

Tallgrass Prairie National Preserve (Figure B.12)

Reference frame:

The park boundary defines the reference frame for Tallgrass Prairie National Preserve (TAPR). The sample within the reference frame consists of 301 400 m line transects.

Procedures:

1. An underlying 200-m grid (fcl_taprgrd200mp) was created to encompass the TAPR boundary. The grid was oriented at 56.31080674° to match the grid that was originally created to support grassland bird monitoring at TAPR. This orientation may or may not have been randomly selected. The orientation was intended to minimize the influences of built features (e.g. roads, fences) oriented in cardinal directions.

2. Points were located at grid vertices (fcl_taprgrd200mt) using “data management tools” in the “ArcToolbox” found in ESRI ArcMap 9.0. However, in order to match the exact location of bird monitoring sites, the grid was shifted.
3. The points (fcl_taprgrd200mt) were clipped (fcl_taprgrd200mClipt) using the TAPR boundary (taprbndp).
4. The midpoint of the first line transect was selected to correspond with grassland bird monitoring points at a 400-m interval. Transect start-, mid-, and end-points were combined in a single file (fcl_taprinpt).
5. Line transect start- and end-points were connected with hand-digitized lines (fcl_taprinpl). The line transects were then clipped to the park boundary (fcl_taprinp_clipl). InpID serves as the unique identifier field.
6. For display purposes, squares were created to encompass line transects (fcl_taprinpp). InpID serves as the unique identifier field.

Wilson’s Creek National Battlefield (Figure B.13)

Reference frame:

At Wilson’s Creek National Battlefield, reference frame strata were selected to reflect park management priorities. A classification scheme of four priority categories was developed. Category 1 areas included sites that support the Missouri bladderpod, a prairie planting of exceptional quality, high quality oak-hickory forests, and a restored oak savanna. Category 2 areas included restored native warm season grasslands and woodlands that buffer a number of category 1 sites that are of high importance for park interpretation. Category 3 areas included a mixture of successional woodlands and grasslands. Category 4 areas included developed areas and regularly mowed fescue fields. Category 4 areas are not included in the reference frame. The priority levels were determined based on discussions with Gary Sullivan, chief of resources and maintenance. The sample consists of 171 200-m transects.

Procedures:

1. An underlying 50-m grid (fcl_wicrgrd50mp) was created to encompass the WICR boundary as well as congressionally-approved boundary expansion areas. The 50-m grid resolution was selected as a scale that would accommodate current and future monitoring projects. The grid was located using a random start. The grid was oriented at 45° to minimize the influences of built features (e.g. roads, fences) oriented along cardinal directions. Points were located at grid vertices (fcl_wicrgrd50mt) using “data management tools” in the “ArcToolbox” found in ESRI ArcMap 9.0.
2. The points (fcl_wicrgrd50mt) were clipped (fcl_wicrgrd50mClipt) using the WICR boundary (wicrbndp) and the Sweeney property boundary (Sweenybndp), a recent park addition not yet incorporated in the boundary file as of December 2006.

3. The midpoint of the first line transect was selected from the available points (see fcl_wicrgrd50mClipt) by first selecting a point on the western edge of the park. The first line transect midpoint was randomly located at WicrGrdID 14842 (see fcl_wicrgrd50mClipt). From this anchor point, additional line transect midpoints were selected in all upward, downward, and lateral directions (i.e., no diagonals).
4. Line transect start- and end-points were designated in lateral directions at 100 m NE and 100 m SW from the line transect midpoint. Transect start-, mid-, and end-points were combined in a single file (fcl_wicrinpt).
5. Line transect start- and end-points were connected with hand-digitized lines (fcl_wicrinpl). InpID serves as the unique identifier field.
6. Points (fcl_wicrinp_clipt) and line transects (fcl_wicrinpl) were then clipped to exclude areas designated as category 4 areas in the reference frame (fcl_wicrexoticreframe).
7. The line transects were identified by the same primary key as the line transect midpoint (InpID).
8. For display purposes, squares were created to encompass line transects (fcl_wicrinpp). The unique identifier InpID allows data to be linked with line transects (fcl_wicrinpl_clip) or line transect midpoints (fcl_wicrinpt_clip).

Arkansas Post National Memorial - Main Unit Exotic Plant Search Units



Figure B.1. Invasive exotic plant monitoring reference frame for Arkansas Post National Memorial, Main Unit.

Arkansas Post National Memorial - Osotouy Unit Exotic Plant Search Units

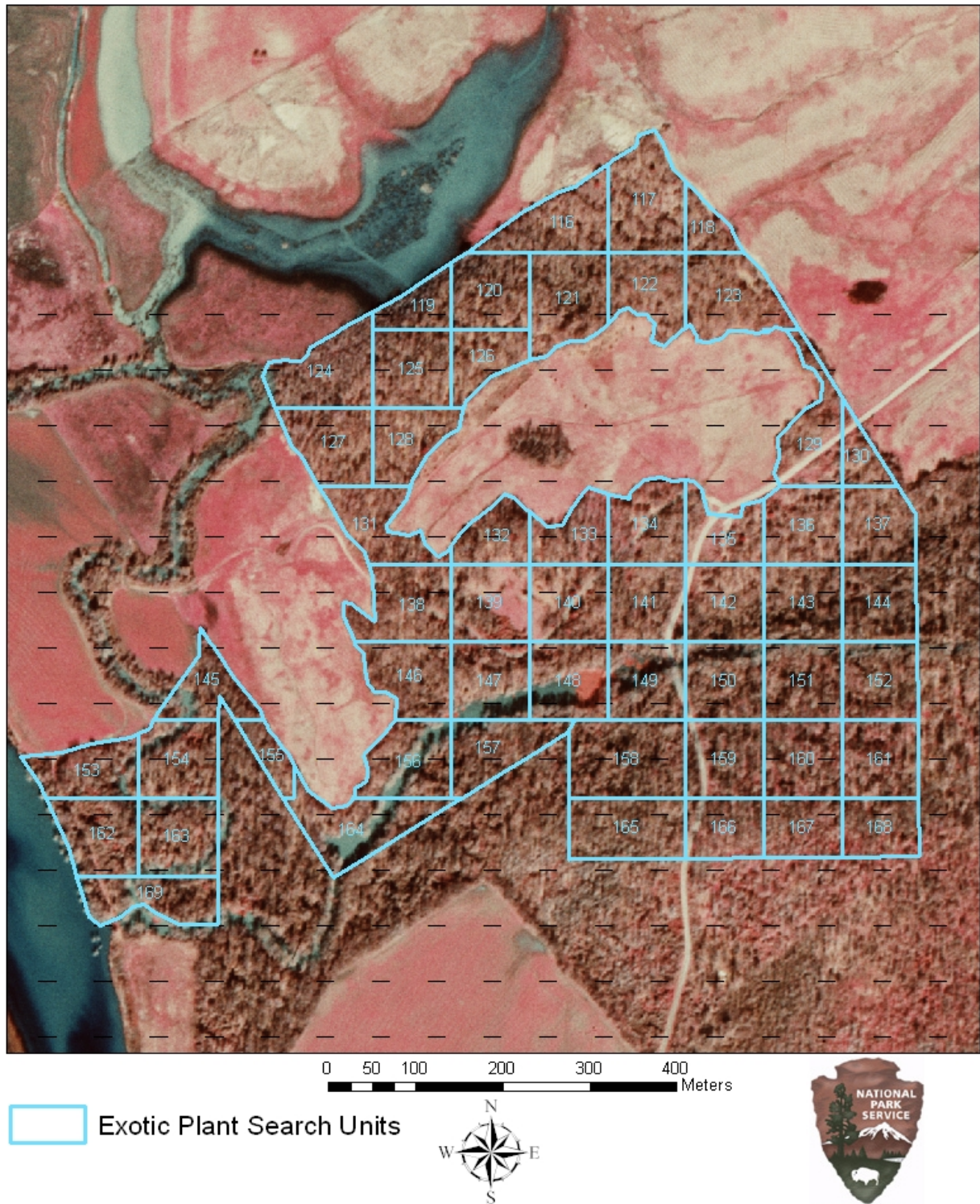


Figure B.2. Invasive exotic plant monitoring reference frame for Arkansas Post National Memorial, Osotouy Unit.

Cuyahoga Valley National Park Exotic Plant Search Line Transects

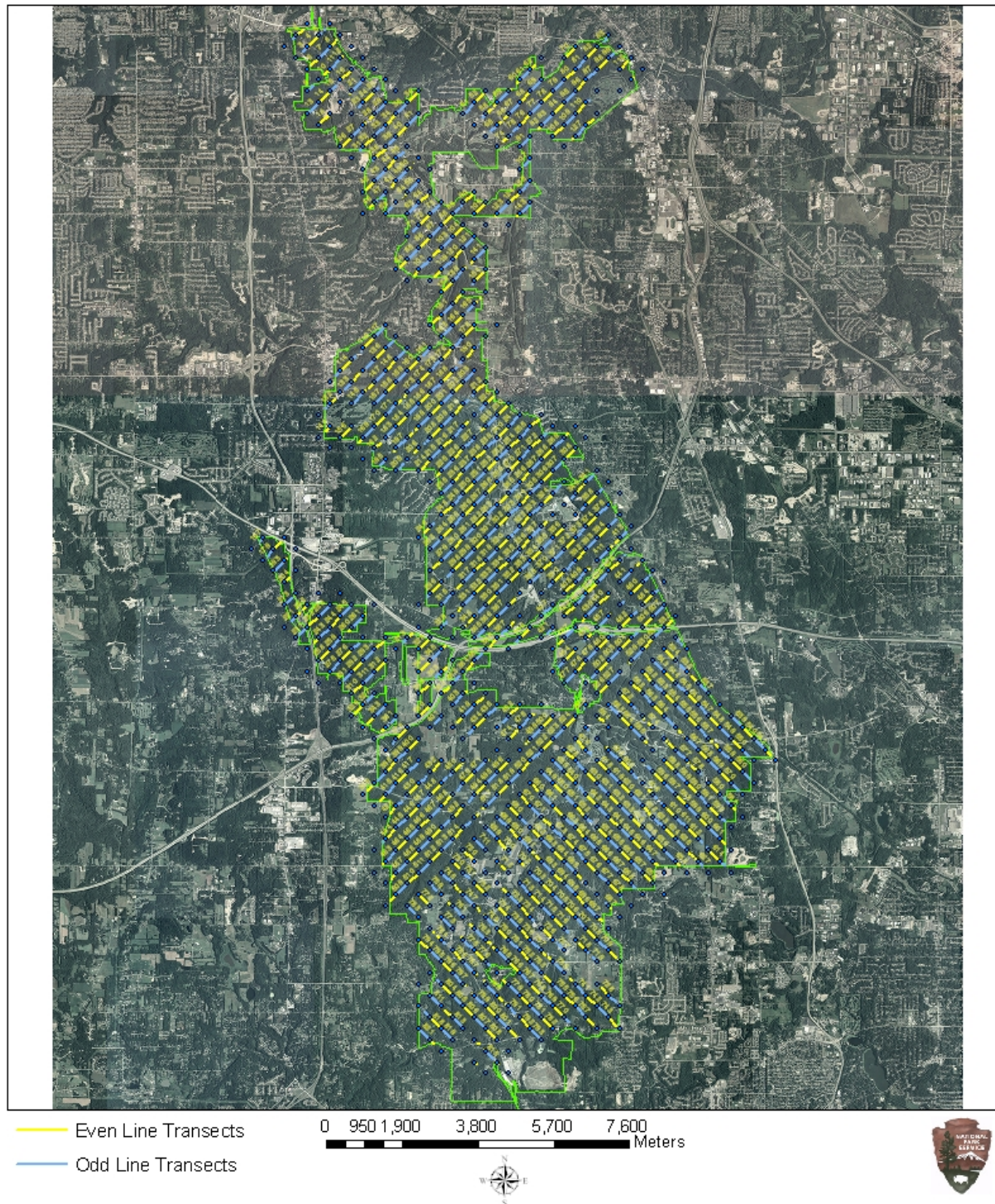


Figure B.3. Invasive exotic plant monitoring reference frame for Cuyahoga Valley National Park.

Effigy Mounds National Monument Exotic Plant Search Line Transects

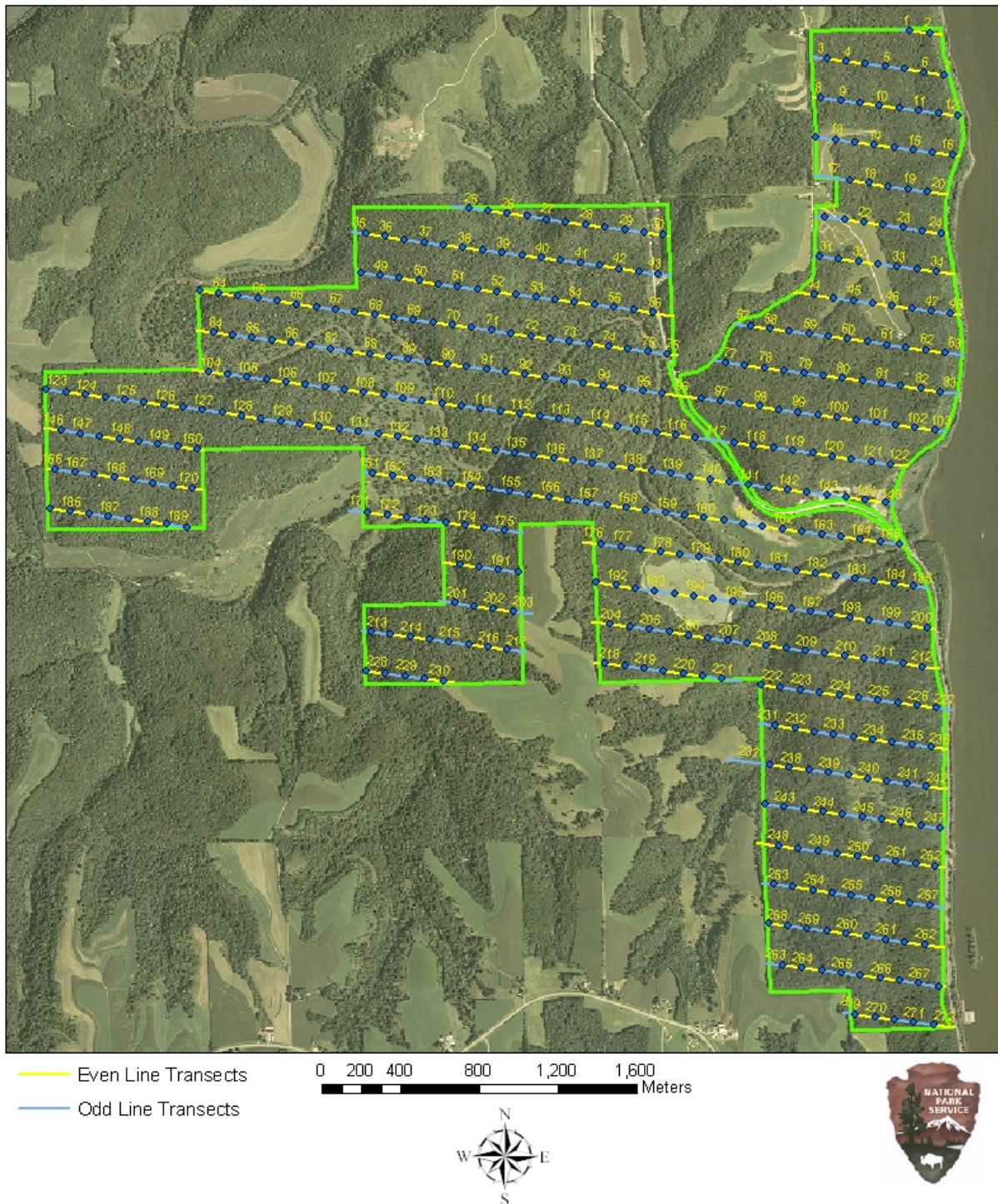


Figure B.4. Invasive exotic plant monitoring reference frame for Effigy Mounds National Monument.

George Washington Carver National Monument Exotic Plant Search Units

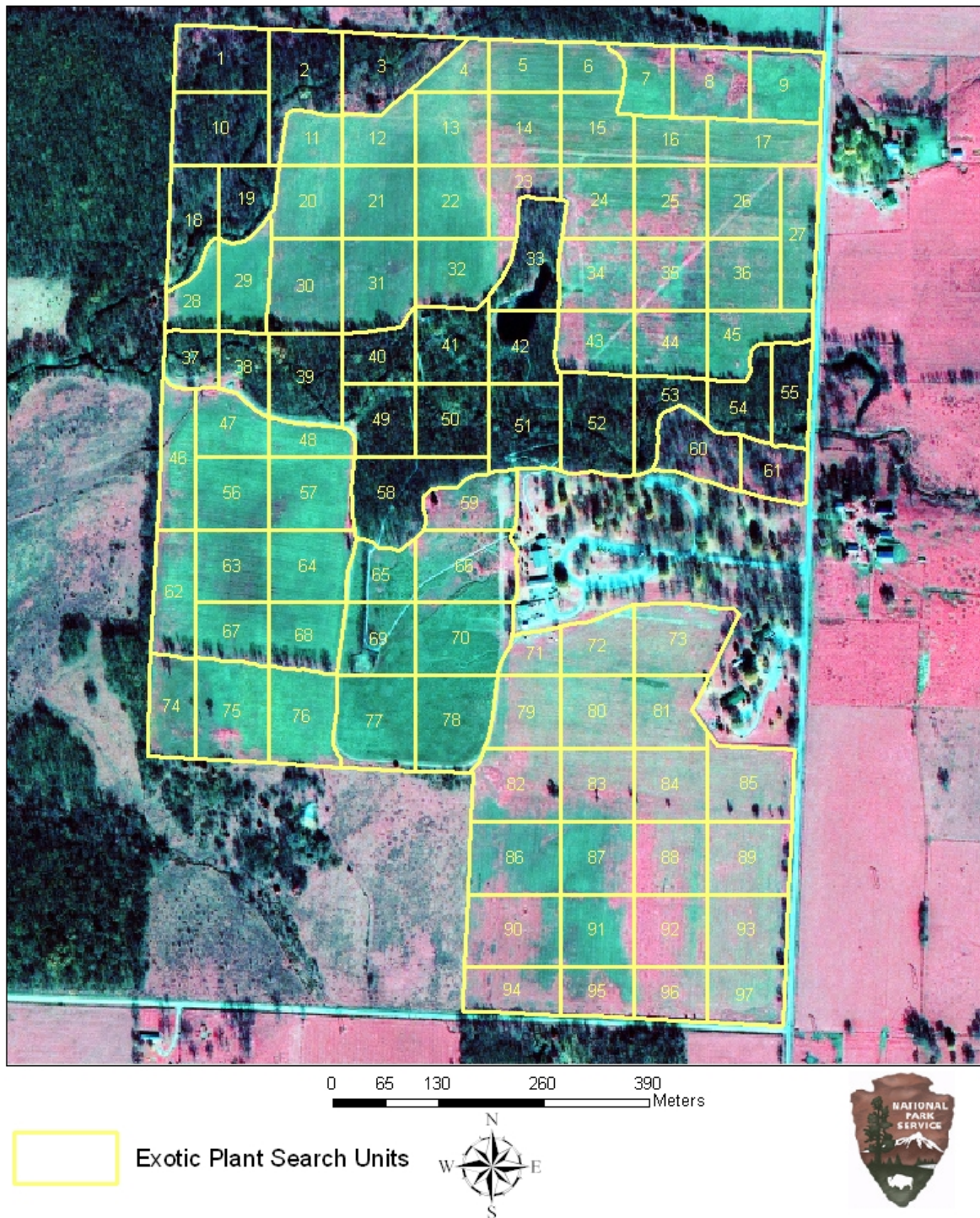


Figure B.5. Invasive exotic plant monitoring reference frame for George Washington Carver National Memorial.

Herbert Hoover National Historic Site Exotic Plant Search Units

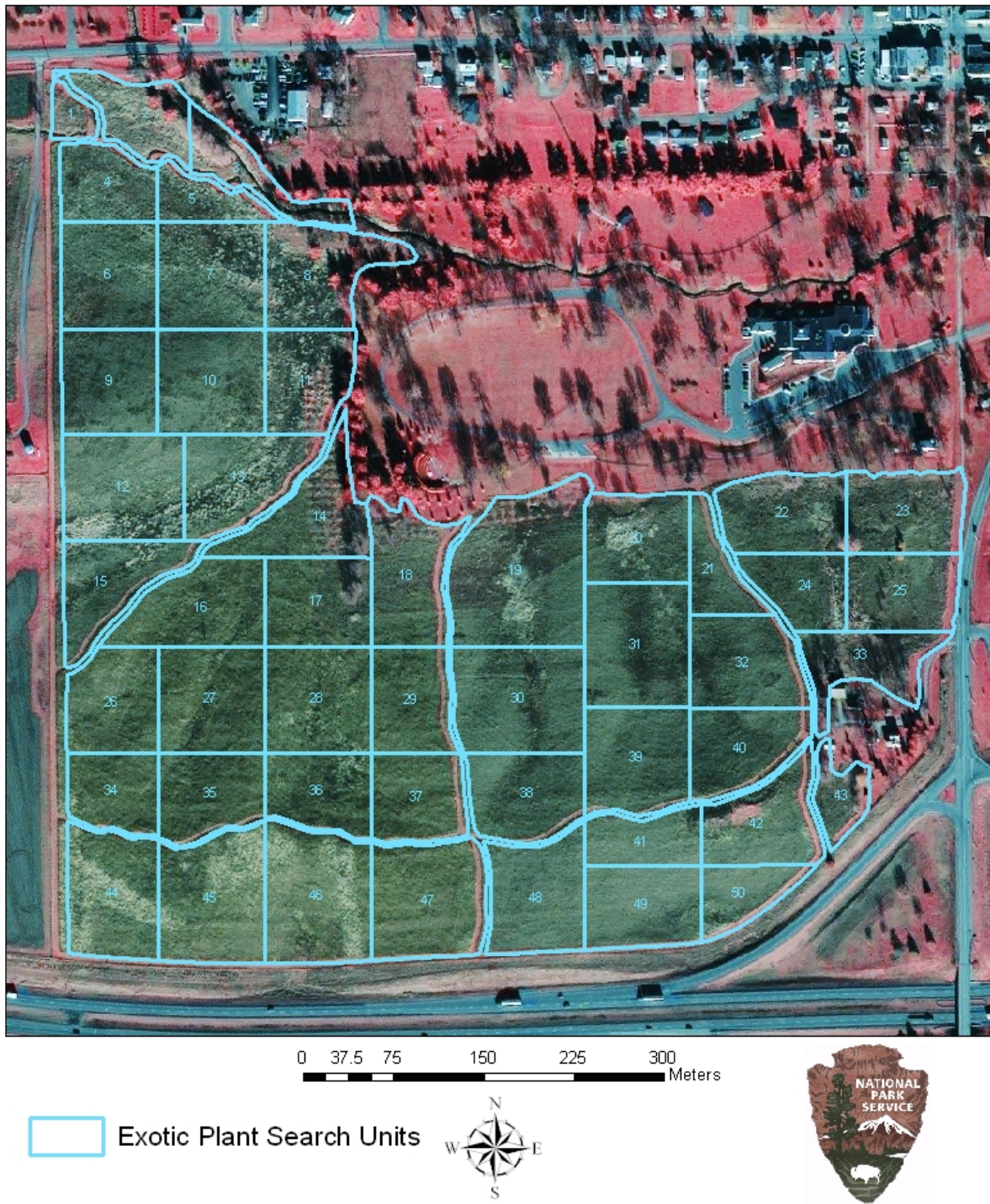


Figure B.6. Invasive exotic plant monitoring reference frame for Herbert Hoover National Historic Site.

Homestead National Monument of America Exotic Plant Search Units

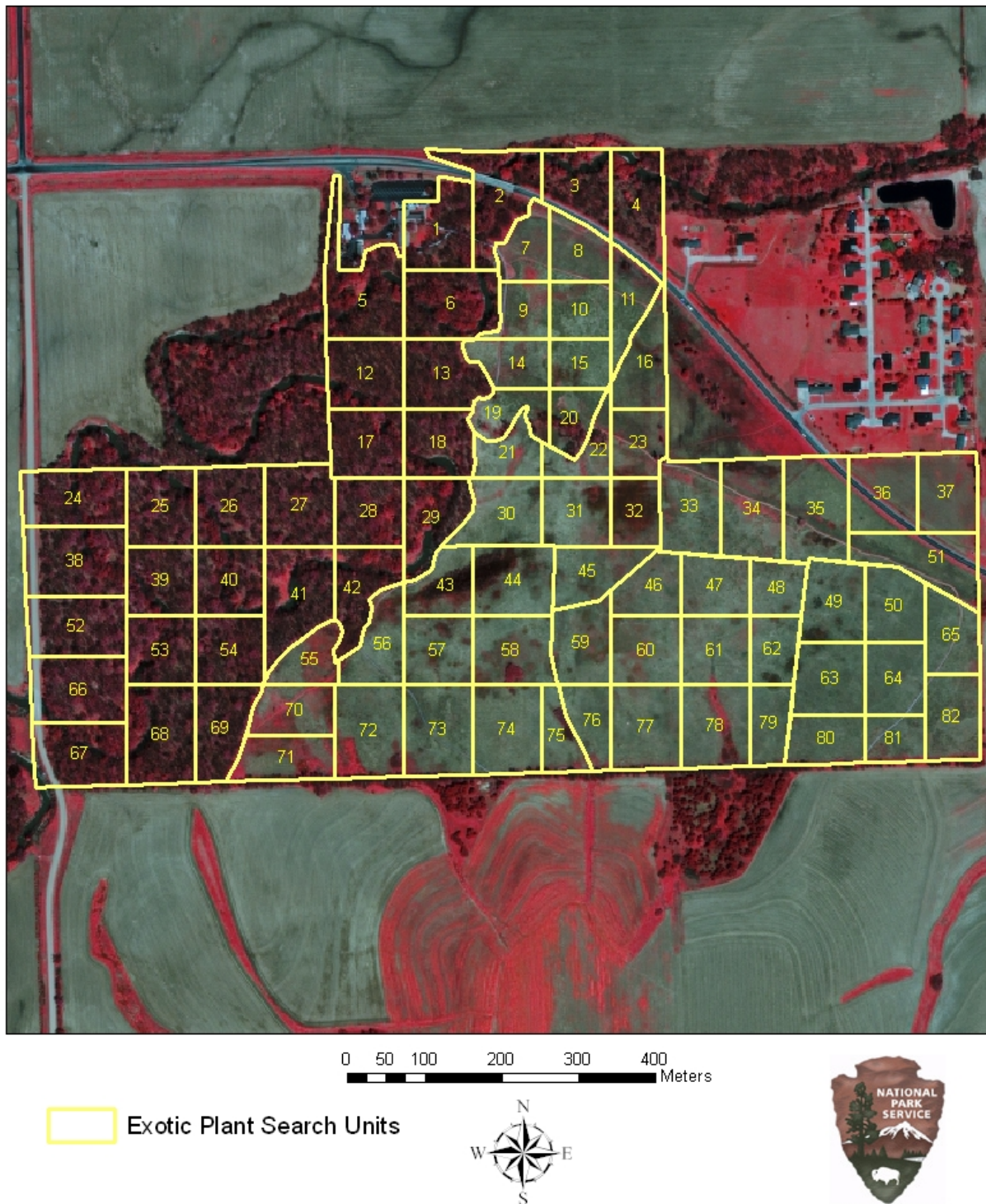


Figure B.7. Invasive exotic plant monitoring reference frame for Homestead National Monument of America.

Hopewell Culture National Historic Park Exotic Plant Search Units

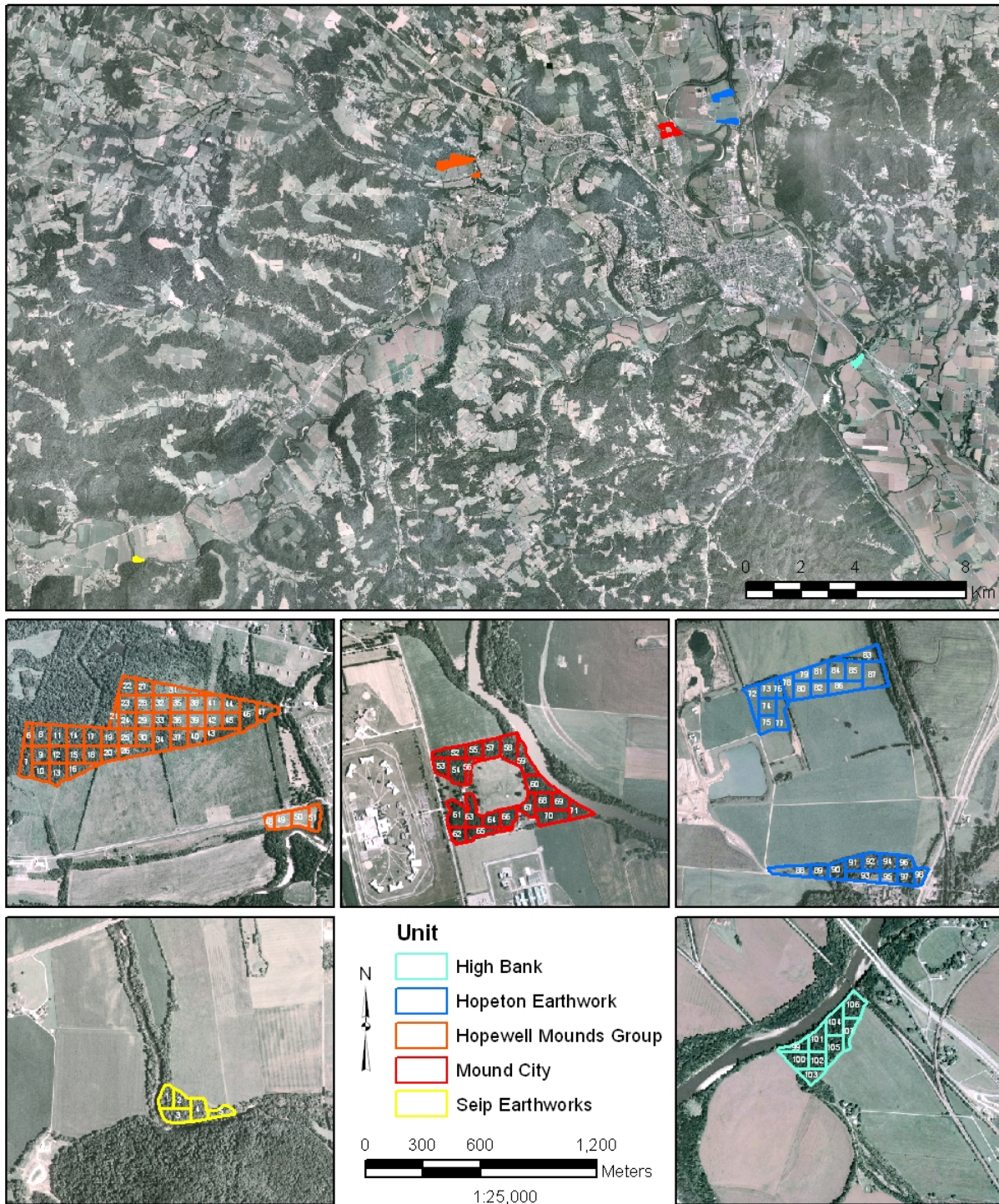


Figure B.8. Invasive exotic plant monitoring reference frame for Hopewell Culture National Monument.

Lincoln Boyhood National Memorial Exotic Plant Search Units

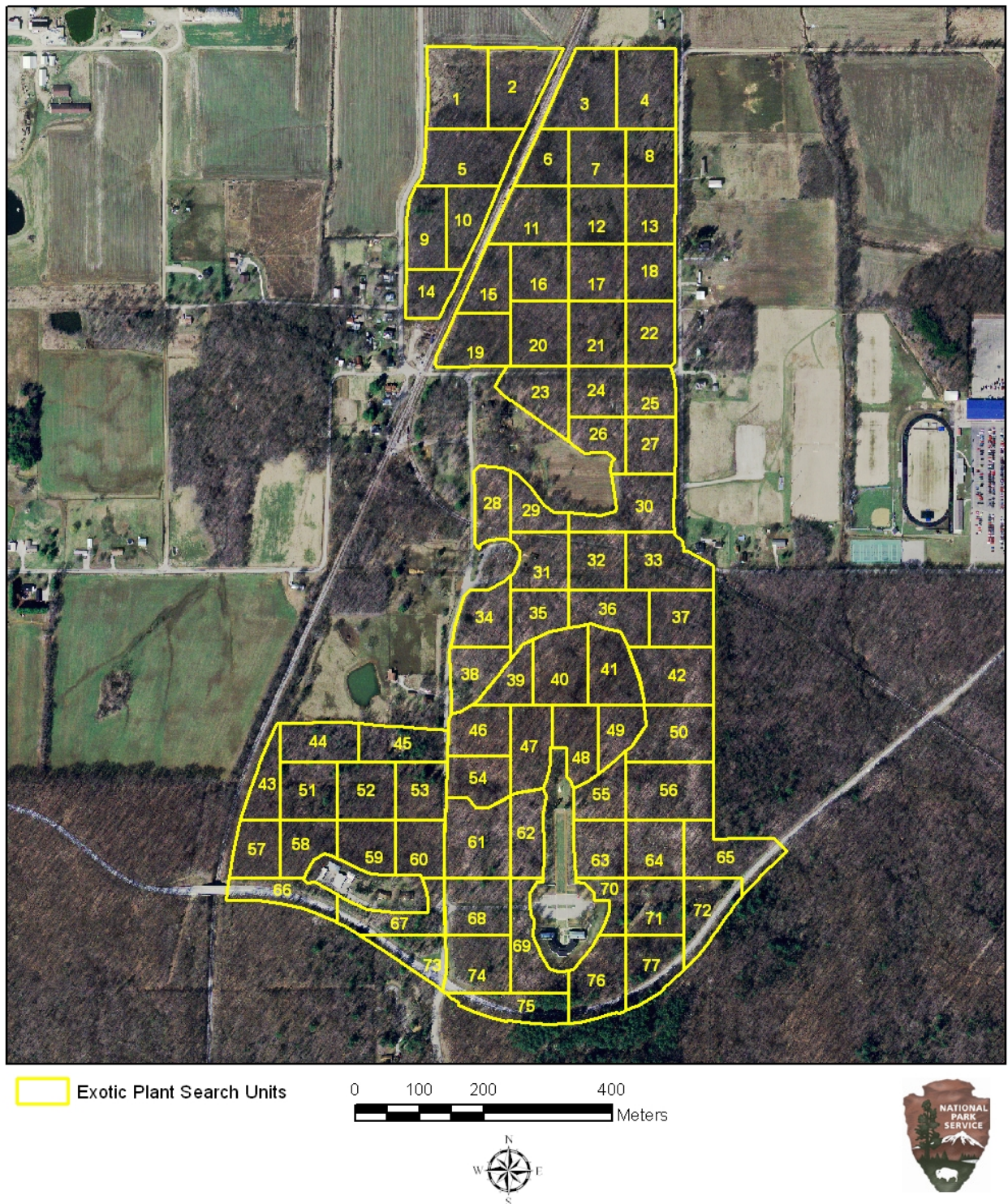


Figure B.9. Invasive exotic plant monitoring reference frame for Lincoln Boyhood National Monument.

Pea Ridge National Military Park Exotic Plant Search Line Transects

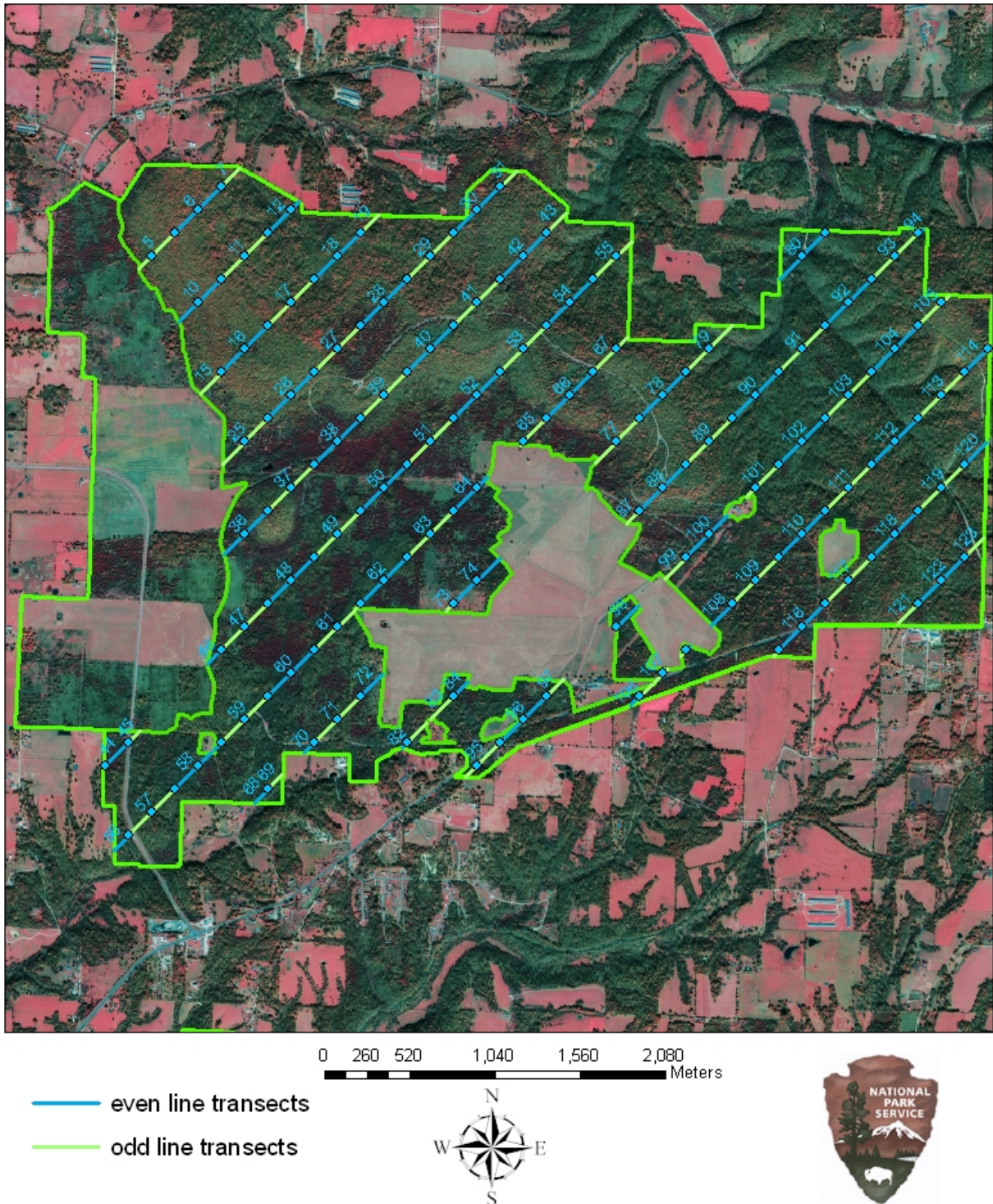


Figure B.10. Invasive exotic plant monitoring reference frame for Pea Ridge National Military Park.

Pipestone National Monument Exotic Plant Search Units



Figure B.11. Invasive exotic plant monitoring reference frame for Pipestone National Monument.

Tallgrass Prairie National Preserve Exotic Plant Search Line Transects

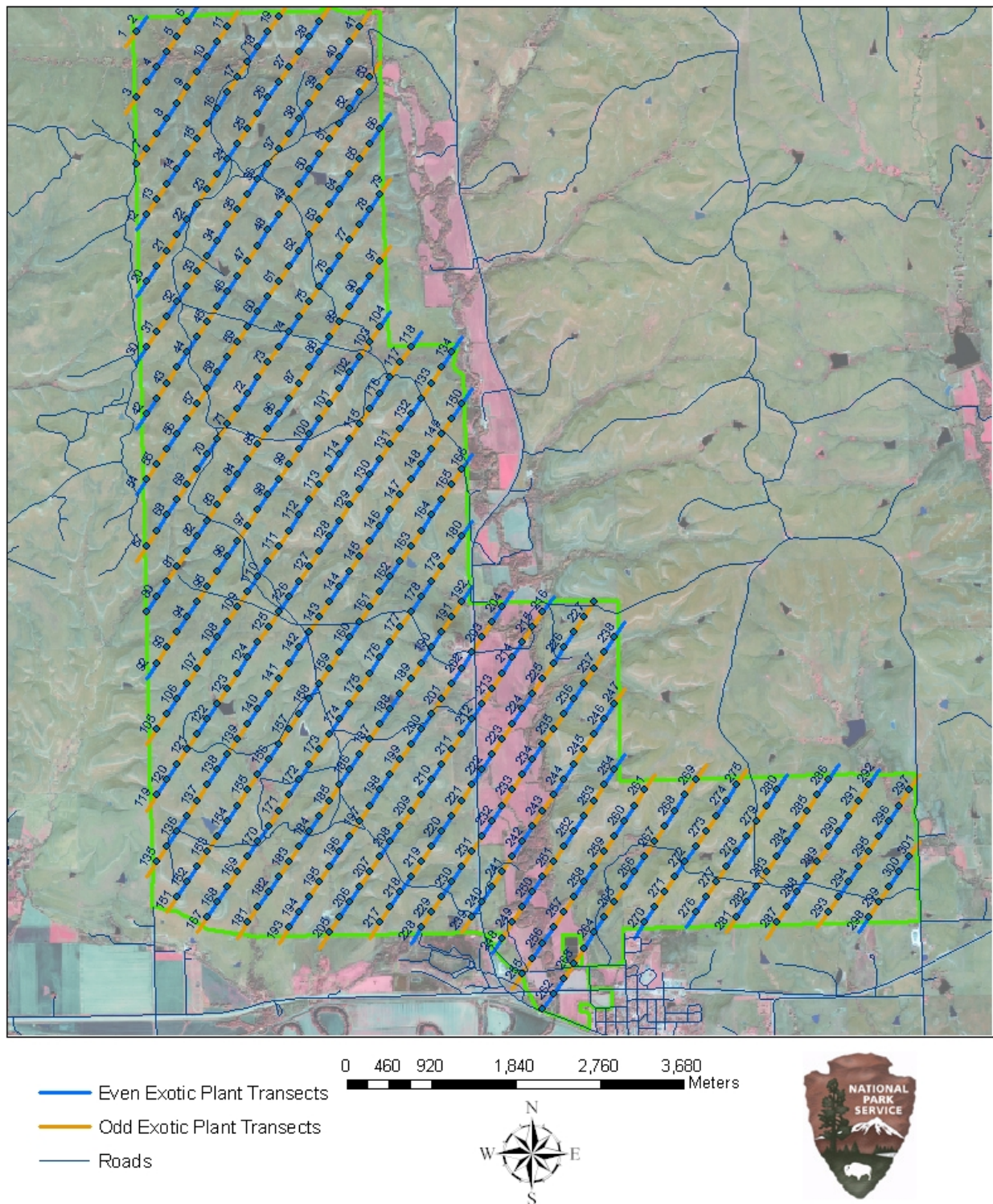


Figure B.12. Invasive exotic plant monitoring reference frame for Tallgrass Prairie National Preserve.

Wilson's Creek National Battlefield Exotic Plant Search Line Transects



Figure B.13. Invasive exotic plant monitoring reference frame for Wilson's Creek National Battlefield.

Appendix C: A Rapid Invasive Plant Survey Method for National Park Units with a Cultural Focus by Craig C. Young and Jennifer L. Haack
(<http://science.nature.nps.gov/im/units/html/articles.cfm>)

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**Invasive Exotic Plant Monitoring Protocol
Heartland Network I&M Program**

Standard Operation Procedure 1: Field Work Preparation

Version 1.00 (7/1/2007)

Revision History Log:

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

I. Procedures

1. Prior to the field season each year, all observers should review the entire protocol.
2. The project manager records observer names, travel hours, field hours, and field notes.
3. The project manager provides an overview of the project scope and methods. Prior to sampling, the project manager will provide a map of the park and reference frame.
4. Equipment should be checked before visiting the field to provide sufficient time for ordering and repairing equipment. The following equipment is needed:

Exotic plant monitoring

- Trimble GeoXT GPS units (Figure 1), including external antenna.
- Background files with DOQQ, park boundary, search units or line transects.
- Laptop computer with Pathfinder software, ArcGIS, navigation files, and shape files.
- Data sheets (including 25% on write-in-the-rain paper).
- Waterproof map of the park with search units or line transects.
- Radios with microphones for communication among observers.
- Guides needed to identify exotic plants, including photographs of plants and look-alike species.
- Pencils, sharpies.
- Hand lens.
- Compass.
- Field notebook to record field observations and press plants.
- Unknown plant specimen forms.
- Plant press.
- Backpacks.

Miscellaneous items

- First aid kit
 - Cell phone
 - Sun screen
 - Insect repellent
 - Water
5. The background, search unit, and line navigation files are located on the network server.



Figure 1.1. Trimble GeoXT GPS unit

**Invasive Exotic Plant Monitoring Protocol
Heartland Network I&M Program**

Standard Operation Procedure 2: Observer Training

Version 1.00 (7/1/2007)

Revision History Log:

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

I. Training Observers in Navigation

Observers are expected to be able to independently navigate in the field using a GPS unit (SOP 3 and 4).

1. Train on the GPS unit model(s) that will be used in the field—normally the GeoXT.
2. Use line transects developed for Wilson’s Creek National Battlefield to practice navigation.
3. Provide instruction on the following (See SOP 4):
 - a. Powering unit on and off.
 - b. Opening multiple navigation files (e.g., background files and data files).
 - c. Confirming zone and datum.
 - d. Ensuring correct identification of search unit/line transect number on the GPS unit.
 - e. Navigation along lines and across search units.
 - f. Setting and changing waypoints.
 - g. Navigating between waypoints.
 - h. Understanding correspondence between map and GPS, including search unit/line transect numbers and compass directions.
 - i. Adjustment of PDOP filter.
 - j. Use of map, compass, and pacing in conjunction with GPS navigation.
4. Observers must demonstrate all of the above without assistance.

II. Training Observers in Plant Identification

Observers are expected to be familiar with plant taxonomy and terminology in order to become quickly familiar with invasive exotic plants (IEPs) encountered at network parks. Suggestions for training field botanists are listed below:

1. Provide exotic plant watch lists that include the species that observers are likely to encounter in the field
2. Prior to the start of the field season, all field botanists should:
 - a. Review photographs, taxonomic keys, herbarium sheets, and notes on field identification.
 - b. Practice plant identification, making use of herbarium specimens where possible.
 - c. Spend time in the field to become familiar with the IEPs on the watch lists.
 - d. Focus training efforts on field identification rather than on formal taxonomy.
 - e. Attend training if available.
3. Provide lists that highlight key vegetative characteristics used in field identification. Names and descriptions of look-alike species should also be provided. Observers should be encouraged to improve on keys.
4. Incorporate plant identification quizzes into field work to improve plant identification skills.

III. Training Observers in Foliar Cover Estimates

Foliar cover estimates provide an estimate of IEP abundance. Consequently, consistent measurements are important for tracking changes in cover over time. However, obtaining consistent estimates among observers is notoriously difficult. This problem is exacerbated with IEP monitoring, which requires integrating abundance over extremely large areas.

1. Foliar cover measures a vertical projection of the leaf area. This can be viewed as the ground area that would be obscured from a downward projection of light above the plant.
2. Conceive of plant cover in 10 m^2 units. Cover classes 1 and 2 should be recognized as portions of 10 m^2 units.
3. Train observers on cover estimation in a group setting, allowing for discussion of each other's estimates. With practice and discussion, foliar cover estimates by observers should begin to converge.
4. Encourage observers to memorize the cover class scale: 0=0, 1=0.1-0.9 m^2 , 2=1-9.9 m^2 , 3=10-49.9 m^2 , 4= 50-99.9 m^2 , 5=100-499.9 m^2 , 6= 499.9-999.9 m^2 , and 7=1,000-4,999.9 m^2 .

5. Practice estimating cover for different life-forms, such as forbs, grasses, and shrubs.
6. Throughout the sampling season, review foliar cover estimation. Early in the field season, observers should calibrate themselves daily. Weekly calibration is recommended thereafter.
7. Ensure good communication among the crew about observer patterns of cover estimation.
8. As vegetation dies back, discuss estimation standards for estimating foliar cover of senescing vegetation.

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**Invasive Exotic Plant Monitoring Protocol
Heartland Network I&M Program**

Standard Operation Procedure 3: Field Survey Methods

Version 1.00 (7/1/2007)

Revision History Log:

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

I. GPS Navigation Files

1. Additional information on GPS operation and file management is provided in SOP 4.
2. Raster background files (*.tif) consist of a DOQQ, invasive exotic plant (IEP) search units or line transect, and points on transects. The background files may include features such as trails, roads, streams, and park boundaries (see SOP 4). The filename structure for raster background files is as follows: Rectified[parkcode]INPBackgroundGPS. Maps corresponding with the background files are available as *.pdf files.
3. The files are uploaded in Pathfinder Office using the data transfer function.
4. Two types of files can be uploaded to the GeoXT: data files and background files. Examples of data files are import (.imp) and waypoint (.wpt) files (Figure 3.1), while .tif files are an example of background file (Figure 3.2). A .tif file must always be associated with a world file (.tfw). Both file types can be displayed on the map screen in TerraSync.

II. File Transfer for Background and Data Files to GeoXT

1. Pathfinder and Microsoft ActiveSync must be loaded on the PC.
2. Put the GeoXT into the charging cradle. Attach the USB cable to the charging cradle and to the PC.
3. Once the GeoXT is locked in the cradle, Microsoft ActiveSync should automatically start. When a dialog box appears answer *Guest Relationship*. (Will not be asked this with the 2005 series.)

4. Once Microsoft ActiveSync is running (indicated by green color), open Pathfinder Office (Figure 4.3).
5. In Pathfinder Office check to see if the coordinates are set correctly for the file(s) to be transferred. Click *Options/Coordinate System* and make corrections as needed.
6. In Pathfinder Office, click on *Utilities/Data Transfer* (Figure 4.4). A message will appear: *Connecting to data logger*. This connection will happen quickly or will not work due to problems with the set up. If a problem occurs, check the cabling and the sequence of operations. Also ensure that the correct device is selected. For the GeoXT this is *GIS Datalogger on Windows CE*.

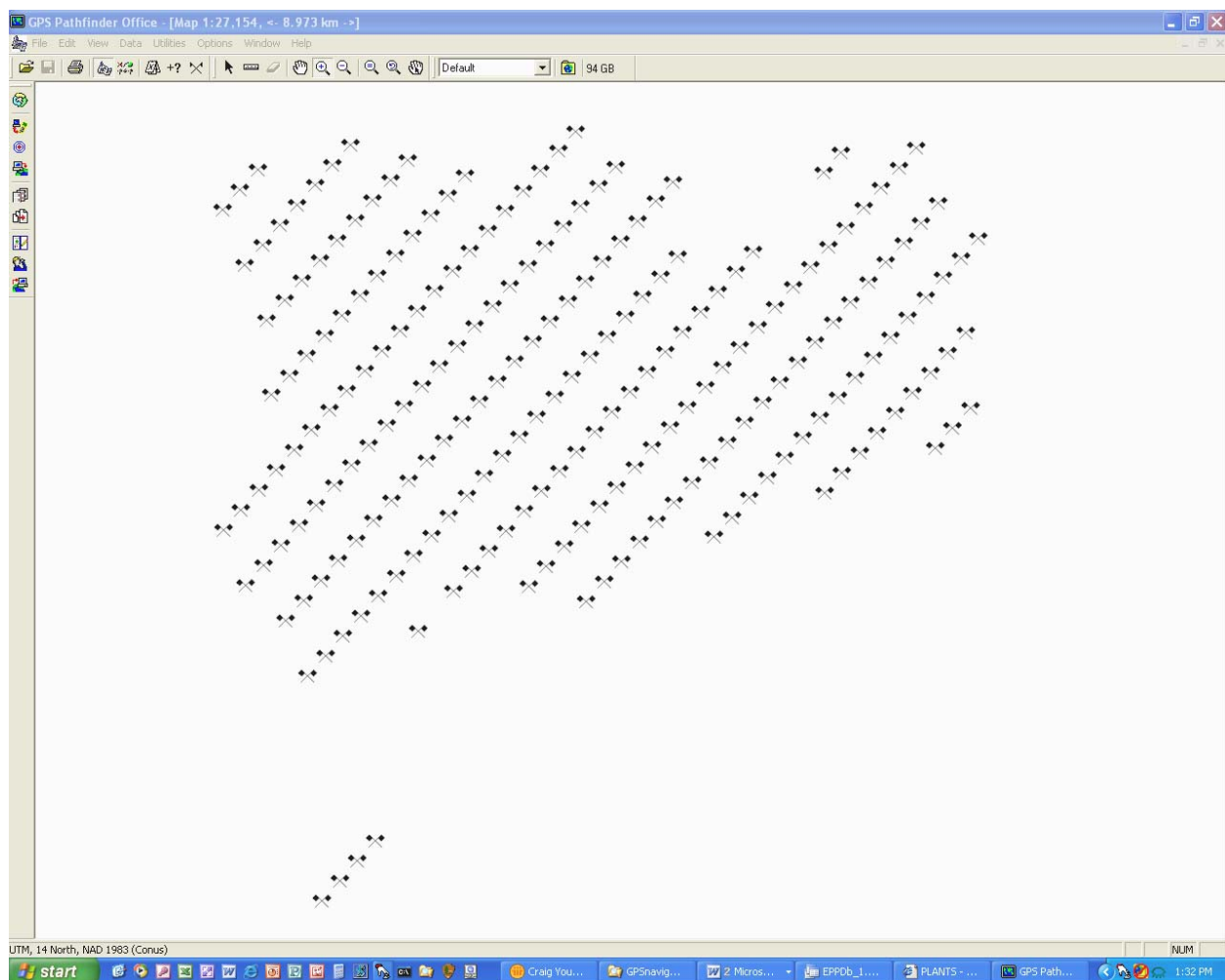


Figure 3.1. Waypoint file of line transect endpoints for Pea Ridge National Military Park.

7. When uploading data to the GeoXT, the *Send* tab must be active.

8. Click the *Add* button, then choose the correct file type (data, waypoint, background). You may choose more than one file at a time. When all files are chosen, click *Transfer All*.
 - A. Load import and waypoint files as data files.
 - B. Load .tif files as background files.
 - 1) After selecting the background file, a new window will open (Figure 3.5).
 - 2) Click the *Add* button and browse to the file you wish to load. Note: The world file (.tfw) will be hidden, but Pathfinder Office recognizes the file.
 - 3) After selecting your file it will appear in the window with a check mark. (Make sure it is checked).
 - 4) Click the *OK* button. You should now see the file in the Data Transfer window
 - 5) Click *Transfer All*.
 - C. When the transfer is done, click *Close*. Close all programs.

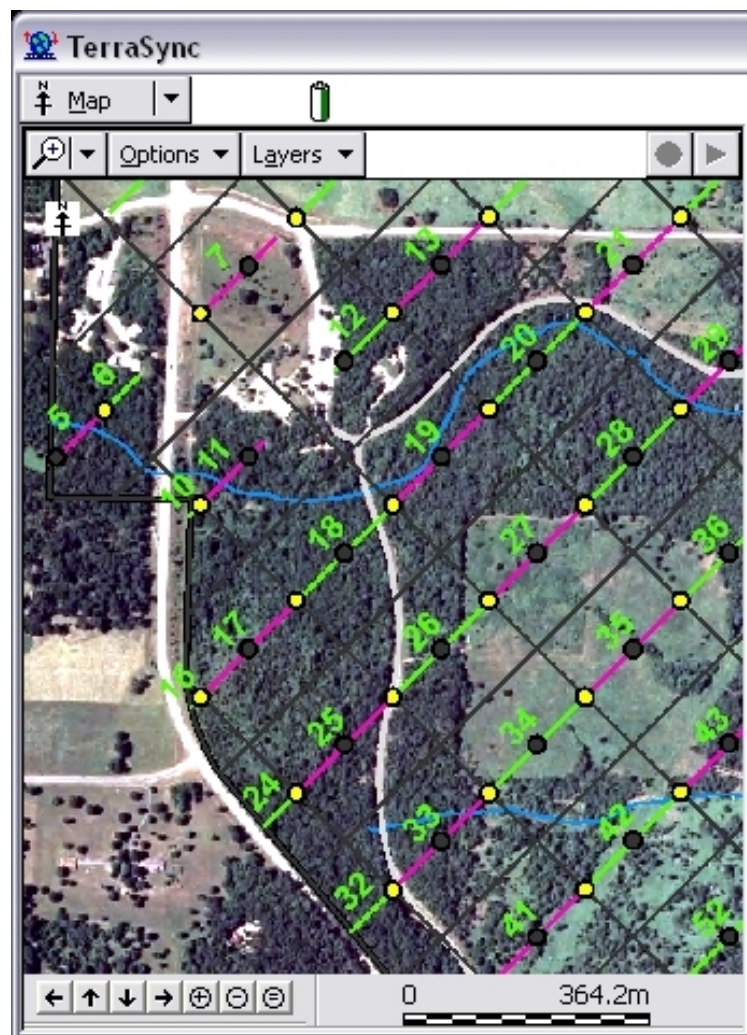


Figure 3.2. Trimble GeoXT set-up for navigation using background (*.tif) files along numbered line transects. The points on the line represent transect start-, mid- and end-points.

III. Displaying files on GPS

1. To display data files:
 - A. Open TerraSync.
 - B. Select the *Data* screen.
 - C. Highlight the file and click *Open*.
 - D. Select the *Map* screen. Vector features can be selected to display attribute information.
2. Background Files
 - A. Open TerraSync.
 - B. Select the *Map* screen.
 - C. Click *Layers* and select *Background File*.
 - D. Highlight the file and click *OK*.
 - E. Use the map function buttons to zoom in and out and pan.

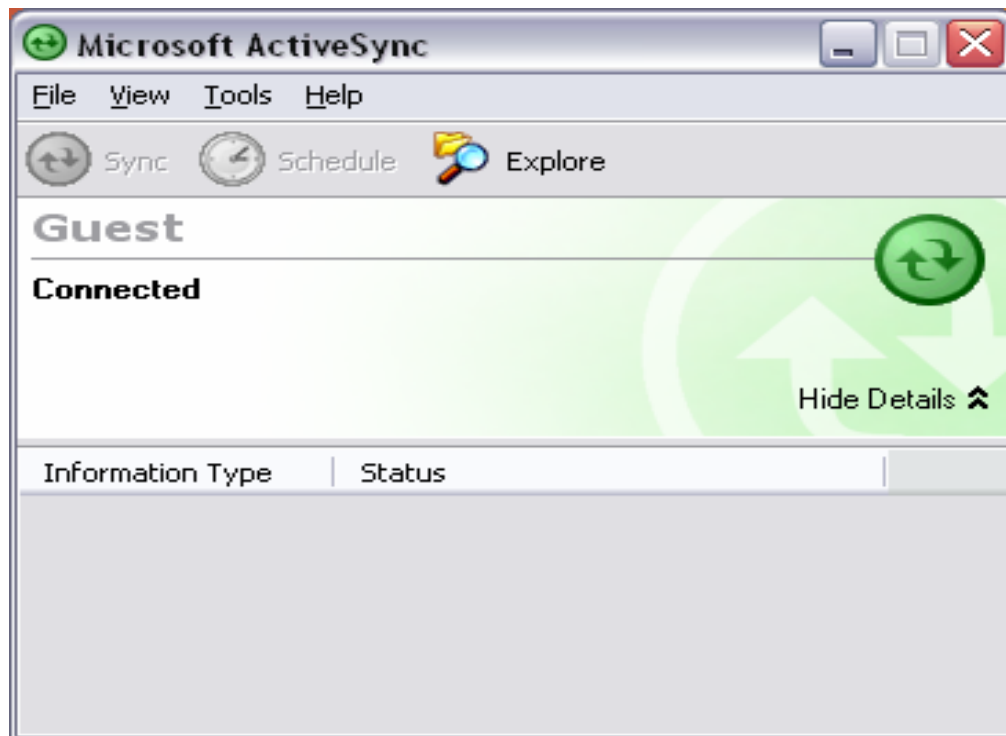


Figure 3.3. Establishing a guest relationship in Microsoft ActiveSync.

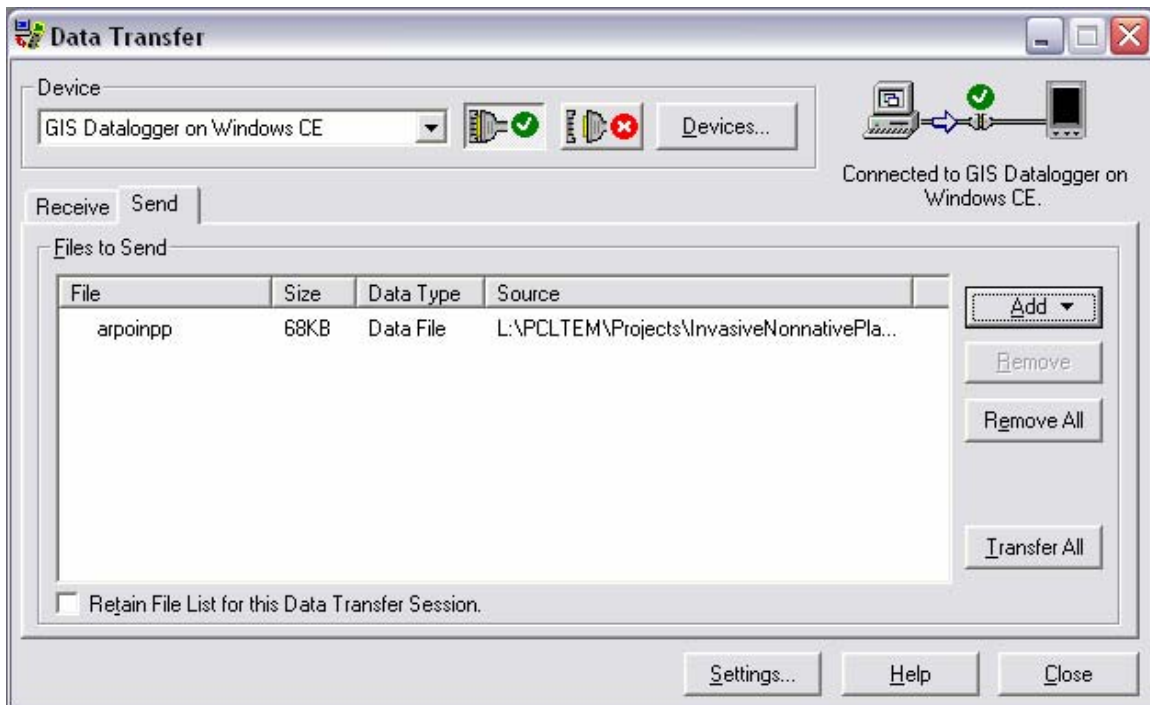


Figure 3.4. Data transfer window in Pathfinder Office.

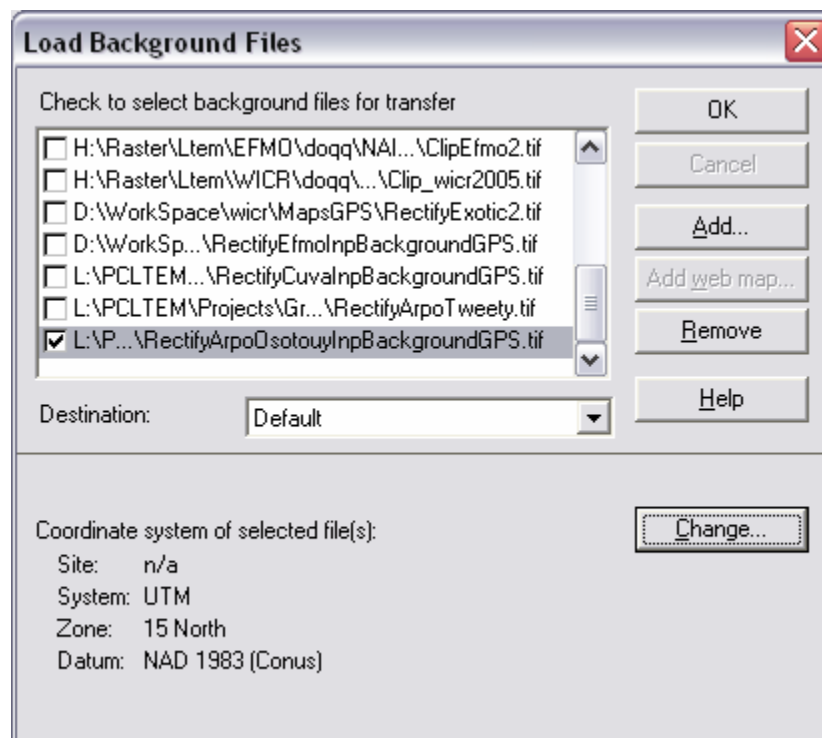


Figure 3.5. Pathfinder Office window for transferring background files.

IV. Navigation

1. To navigate in IEP plant search units (parks $\leq$ 350 acres/142 ha) or along line transects (parks $>$ 350 acres/142 ha), a raster background file is opened in the data window of the GPS unit.
2. Using the background or data file on the GPS unit, the observer can determine his/her location relative to each IEP plant search unit. Prior to surveying a search unit or line transect, the observer must confirm the search unit or line transect number using the information associated with the import file or background file.
3. Observers navigate through IEP plant units or along line transects (Figures 3.6 and 3.7).
4. Navigation should occur with PDOP set to 6.0. However, PDOP can be adjusted upward to the maximum necessary to continue field work.
5. In some parks, rough terrain may preclude access to some search units or line transects. In these instances, navigation notes that identify inaccessible areas and provide guidance on navigation problems should be consulted. Navigation notes are under development and available on the network server.
6. In some instances, the obstacles such as downed trees, thick vegetation, poisonous plants, and stinging insects may require that the observer(s) vary from the planned searched route. This is expected and is a part of the flexibility that is intended for the protocol. The observer will stay as close to the planned search route as is feasible during navigation.

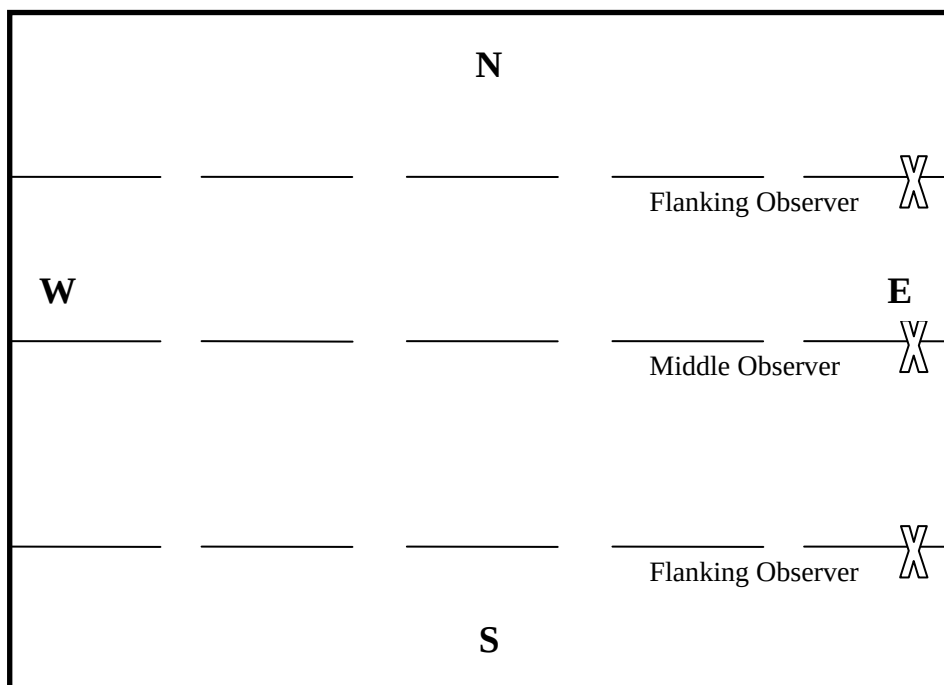


Figure 3.6. Navigation along three roughly equidistant lines in an invasive exotic plant search unit. The “X” indicates the observer locations. The dashed lines identify the lines that will be searched.

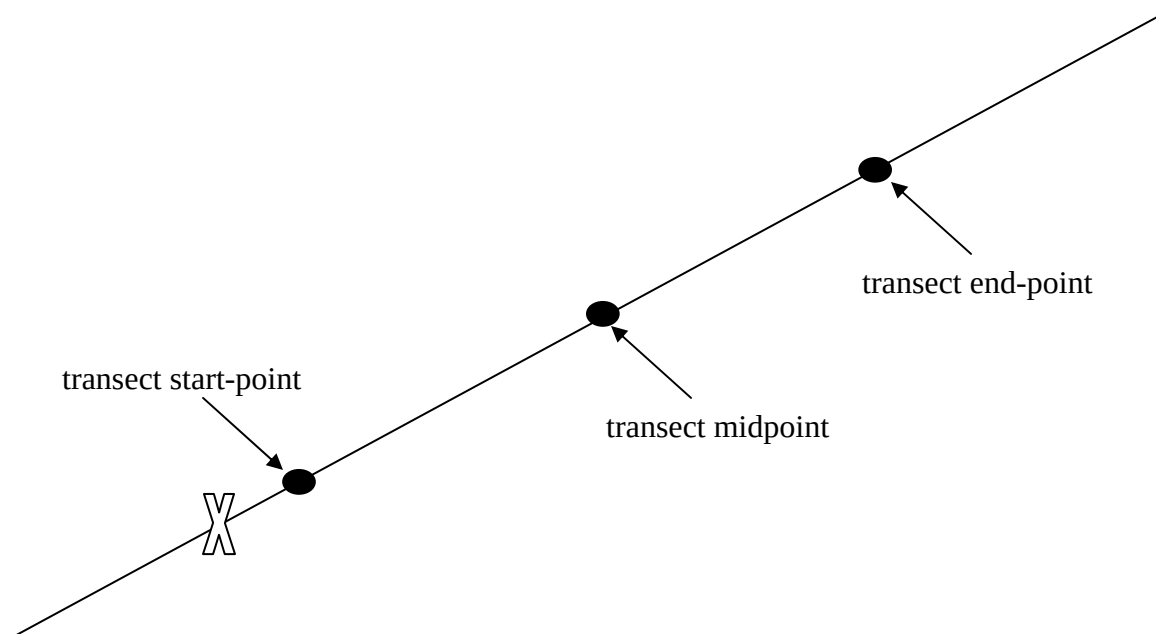


Figure 3.7. Navigation along a line transect during exotic plant monitoring. The “X” indicates the observer location. The observer searches the line between transect start points and end points.

V. Data Collection in IEP Search Units

1. For IEP search units, optimal crew size is three observers. Observers position themselves at equidistant intervals along the edge of the search unit. The two observers closest to the edge of the search unit navigate through the unit using GPS units. The middle observer maintains equal spacing between the flanking observers, but does not use a GPS unit for navigation. The three observers search in an east-west direction unless a strong rationale is provided for searching in a north-south direction (Figure 3.6). Observers search for the plants on the IEP watch lists. The middle observer records all IEPs observed by the crew. Radios with microphones are carried to facilitate communication.
2. Observers identify IEPs in a 3- to 12-m belt when passing through the unit. Within this range, observations are made in the widest possible belt.
3. After navigating through the search unit, observers confer to estimate foliar cover of each watch list IEP observed using the following cover class scale: 0=0, 1=0.1-0.9 m², 2=1-9.9 m², 3=10-49.9 m², 4= 50-99.9 m², 5=100-499.9 m², 6= 499.9-999.9 m², and 7=1,000-4,999.9 m². Data are recorded on data form 1 (Appendix 3A).
4. Observers should take in to account the length of the belt transects. For example, transect length on a square 2-acre (0.8 ha) search unit is approximately 90 m. If 3 transects are searched, total transect length is 270 m. Based on the widths of 3- to 12-m, the park fraction observed could range between 710 and 2840 m². In this case, the maximum cover class potentially assigned to a search unit is 7.
5. Observers have the discretion to search areas beyond the transects within search units. Areas likely to contain IEPs may be visited. Estimates of foliar cover must be made separately for IEPs observed in the belt and plants observed beyond the belt (Appendix 3A).
6. Supposing a view above the plant, foliar cover is the area of ground that would be obscured by the leaf surface area of the plant.
7. IEP cover should be conceptualized using 10 m² units. These 10 m² units serve as a common unit of measurement that facilitates comparisons of foliar cover among observers. Cover classes 1 and 2 should be recognized as a portion of a 10 m² unit.
8. In instances where only two observers are available to survey exotic plant search units, one option is for one observer to focus solely on navigation and the second observer to follow the first on the same line and focus on plant identification and foliar cover estimation.
9. The pace of field work may be increased with the use of a plant collection bag. Enough of an exotic plant specimen (usually a leaf) is collected to serve as a reminder of the observation. When navigation is completed, the observer records the plant identity and foliar cover estimate. Notes may be taken as needed to assist in estimating plant cover.

10. Completed data sheets are given to the project manager. The project manager must ensure that data have been properly recorded before leaving the field.

VI. Data Collection Along Line Transects

1. To navigate along line transects, observers follow the line on the GPS unit (Figure 3.7). The optimal crew size is two observers. One observer focuses solely on navigation and the second observer focuses on identification of plants on IEP watch lists and foliar cover estimation. However, a single observer may navigate and identify exotic plants simultaneously. Observers identify IEPs in a 3- to 12-m belt.
2. The pace of field work may be increased with the use of a plant collection bag. Enough of an exotic plant specimen (usually a leaf) is collected to serve as a reminder of the observation. When the navigation is completed, the observer records the plant taxon and the corresponding foliar cover estimate. Notes may be taken as needed to assist in estimating plant cover.
3. Observers estimate foliar cover of all IEP species observed using the following cover class scale: 0=0, 1=0.1-0.9 m², 2=1-9.9 m², 3=10-49.9 m², 4= 50-99.9 m², 5=100-499.9 m², 6= 499.9-999.9 m², and 7=1,000-4,999.9 m². Data are recorded on data form 1 (Appendix 4A).
4. Observers should take in to account the length of the belt transects. For example, for a 200 m transect, based on 3- to 12-m widths, the total area observed could range between 600 and 2400 m². In this case, the maximum cover class potentially assigned to a search unit is 7.
5. Observers have the discretion to search additional areas, especially those likely to contain exotic plants. For parks with transects located 200 m apart, observers may search a perpendicular distance of up to 100 m from the line transect. For parks with transects located 400 m apart, observers may search up to a perpendicular distance of 200 m from the line transect. Estimates of foliar cover must be made separately for IEPs observed in the 12-m belt and plants observed beyond the belt.
6. Supposing a view above the plant, foliar cover is the area of ground that would be obscured by the leaf surface area of the plant.
11. IEP cover should be conceptualized using 10 m² units. These 10 m² units serve as a common unit of measurement that facilitates comparisons of foliar cover among observers. Cover classes 1 and 2 should be recognized as a portion of a 10 m² unit.
12. Completed data sheets are given to the project manager. The project manager must ensure that data have been properly recorded before leaving the field.

VII. Plant Identification

1. Research specimens may be collected to confirm identification of exotic plant species, especially those that are likely to be identified incorrectly. These specimens are collected and recorded on the data sheet with an unknown specimen code (<park code><inv>_<unknown number>_<date>, e.g., WICRinv_2_07032006). A data form is provided in Appendix 3B.

VIII. Trip Report

1. Following the trip, the project manager writes a trip report describing weather conditions, logistical problems, departures from the protocol, and species identification problems.

Appendix 3A.

Data Form 1: Exotic Plant Monitoring Data Sheet

Observer _____ Park _____ Date _____

Exotic Plant Search Unit/Line Transect #: search unit 22 Direction (circle) E-W or N-S

Exotic Plant Species	Cover in Belt	Cover out of Belt	Exotic Plant Species	Cover in Belt	Cover out of Belt

Access note : _____

Exotic Plant Search Unit/Line Transect #: search unit 22 Direction (circle) E-W or N-S

Exotic Plant Species	Cover in Belt	Cover out of Belt	Exotic Plant Species	Cover in Belt	Cover out of Belt

Access note : _____

Exotic Plant Search Unit/Line Transect #: search unit 22 Direction (circle) E-W or N-S

Exotic Plant Species	Cover in Belt	Cover out of Belt	Exotic Plant Species	Cover in Belt	Cover out of Belt

Access note : _____

Cover class scale: 0=0, 1=0.1-0.9 m², 2=1-9.9 m², 3=10-49.9 m², 4= 50-99.9 m², 5=100-499.9 m², 6= 499.9-999.9 m², and 7=1,000-4,999.9 m².

Appendix 3B.

Unknown Data Sheet

Park:_____

Unknown Code:_____

Transect & Plot:_____

Date:_____

Plant Type & General Description: herb shrub tree vine grass sedge other_____

Most salient feature:

Leaf Characteristics:

Leaf Type: (cmpd/simple, arrangement, etc.)

Margin:

Other: (pubescence, sap, stipules, etc)

Stem Characteristics: (shape, pubescence, bud)

Flower Characteristics: (color, location, floral formula)

General and Microhabitat Characteristics:

Collected: Yes No

Best Guess:

Confirmed to be:

**Invasive Exotic Plant Monitoring Protocol
Heartland Network I&M Program**

**Standard Operation Procedure 4:
Using the Trimble GeoXT (TerraSync version 2.5)**

Version 2.01 (07/01/2007)

Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.0	Dec. 2004	J. Haack	Pages 18-34	New version of TerraSync	1.01
1.01	Apr. 2006	J. Haack	Entire document	Troubleshooting and log	1.02
1.02	Oct. 2006	J. Haack	Pages 32-33	Add map displays, XT	1.03
1.03	Nov. 2006	C. Young	Excerpted GeoXT info	Focus for protocol	2.00
2.00	Nov. 2006	C. Young	Excerpted GeoXT info	Focus for protocol	2.01

This Standard Operating Procedure explains the procedures that all observers should follow to learn to use Global Positioning System (GPS) for the GeoXT units to collect data and navigate to sample sites.

I. Required Reading

GeoExplorer CE Series: Getting Started Guide

GPS Mapping for GIS with TerraSync and GeoExplorer CE Series or TerraSync Operation Guide v2.50

Basic GPS Data Capture Using TerraSync: A Quick Start Guide

II. Scheduling Field Days

For the GPS unit to function properly and collect accurate geographic locations, at least four satellites must be overhead. In addition, PDOP (positional dilution of precision or the measurement of relative accuracy) must be less than six. Schedule field work at a date and time when the PDOP value is below six and the number of available satellites is at least four. In order to facilitate data collection, ask the GIS Coordinator if the most current almanac is available. The almanac is a set of data that is used to predict satellite orbits over approximately a month long period.

Accessing Current Almanac

The almanac may be accessed in TerraSync on the GeoXT. Choose *Status* in the upper left corner drop down menu (Figure 4.1). Then choose *Plan* in the dropdown menu below it. The

PDOP and satellite orbits for up to 12 hours are shown. Projected PDOP may also be estimated using Pathfinder software.

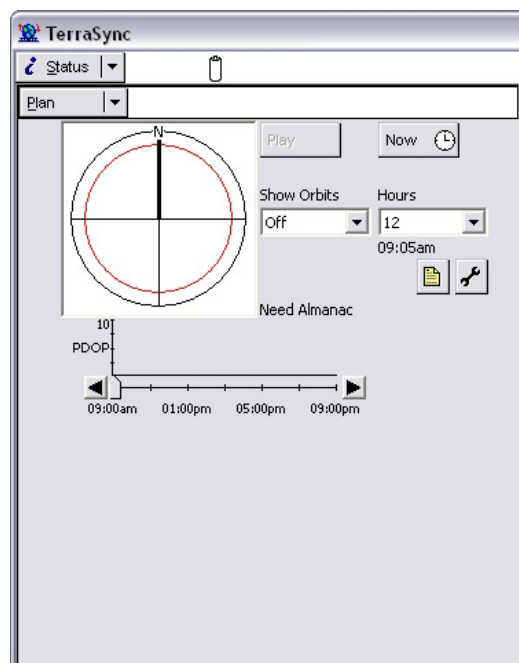


Figure 4.1. Accessing the current almanac on the GeoXT GPS Unit.

III. Pre-Trip Planning

Route Planning

Planning the route is essential. When recording data, knowledge of the area may allow more efficient GPS work and multi-tasking. In addition, the topography of the area may require changes in the GPS configuration. The GIS coordinator will assist with making such changes. Pathfinder Office allows you to create a form known as a “data dictionary” for data collection in the GPS. Following field work, the information recorded with the GPS is downloaded to the computer. The GIS Coordinator is then able to export the information directly into ArcGIS as a table.

Creating a Data Dictionary

See Appendix 4A with definitions for terms with which you are unfamiliar.

1. Open Pathfinder Office and click on *Utilities* and select *Data Dictionary Editor*.
2. Name the file – this will be the name for the data dictionary file. (Examples: PipeFishSampling, MoBladDemo, or DeerSurvey) Fill in the *comment* box with the project that the data dictionary is associated with.
3. Click on *New Feature* and select the *Properties* tab to enter a feature name. Feature names should correspond with field names from each project database. (Examples: pool, deer location, or plot) Next, designate the feature as a point, line or polygon. Click on the *Default*

Settings tab, change the logging interval to 1 second. Click *OK*. If settings require editing, highlight the feature and click on *Edit Feature*. Multiple features may be created per data dictionary.

4. To define feature attributes, click on *New Attribute* and select attributes from the list of *New Attribute Type* (listed below), then click *Add*.
 - b) Menu - Letters, numbers, or other characters. Can select only one value per menu, but can have as many menus in the data dictionary as necessary. Menus are used for comment fields and name fields where you know all possible choices (example is a list of all possible tree species for a certain area or if you have a specific value range 1, 2, 3, 4, etc). Type in *Attribute Name* and click on *New*. Type in attribute value and click *Add*. These could be the names of attributes or measurements associated with attributes. Continue until all attribute values have been entered. Click *OK*.
 - c) Numeric - Numbers only with decimal point. (Use for the id # and value amounts.)
 - d) Text - Letters, numbers, or other characters. Can enter any value – use for the name field if you don't use a menu or comment/note area.
 - e) Date - Collects a date value.
 - f) Time - Collects a time value.
 - g) File Name - Collects a file name.
 - h) Separators - Added to break up the list of attributes and increase readability, but are not attributes and do not contain attribute values.
5. Designate, for all attributes, whether the field entry of an attribute is optional (normal), required, or not permitted. Continue until all attributes have been entered.
6. Save data dictionary.

IV. System Assembly And Settings

When not in use, the GPS unit should be charging in its cradle. Use the surge protector when the cradle is plugged in. If the unit will not be needed for more than 4 months, turn the unit off and store it in the closet.

GeoXT Unit Assembly

The GeoXT requires no assembly, unless the Hurricane Antenna or beacon on a belt (BoB) is used. To attach the Hurricane Antenna attach the antenna to the pole and the cable to the antenna. Finally, plug cable into the top of the GeoXT. The Hurricane Antenna may improve satellite connections in areas with steep topography or dense canopies. To use BoB, attach the serial clip with the accordion cable to the back of the GeoXT. The other end of the cable plugs into the bottom of BoB. Ensure that the GeoXT and BoB are both fully charged before going out and doing field work.

Configuring the GeoXT

In the drop down menu in the upper left corner select *Setup* (Figure 4.2).

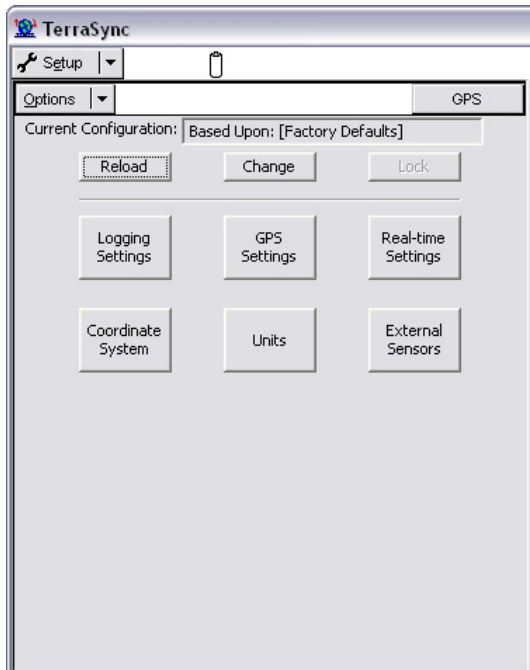


Figure 4.2. Drop down menu for setup for configuring the GeoXT.

The following changes to the factory defaults settings should be made:

1. In *Logging Settings* to change *Antenna Height*, click the wrench button (Figure 4.3). The setting will differ depending on if the internal antenna or the Hurricane Antenna is being used. If internal, change *Type* to GeoXT Internal and *Height* to 1.2m (Figure 4.4). If Hurricane change *Type* to Hurricane, *Part Number* to 50393-50, and *Height* to the correct measurement for the person working the GPS unit (Figure 4.5).

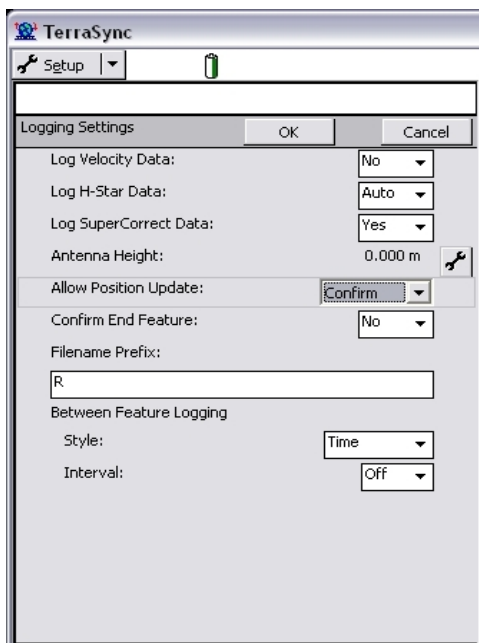


Figure 4.3. Logging settings menu for

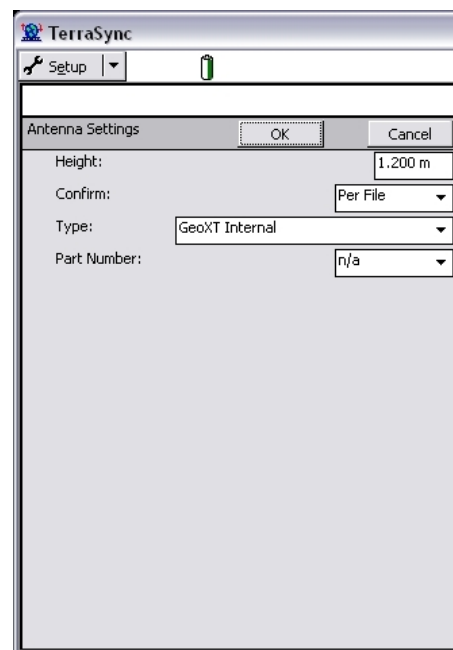


Figure 4.4. Antenna settings for GeoXT internal antenna.

the GeoXT.

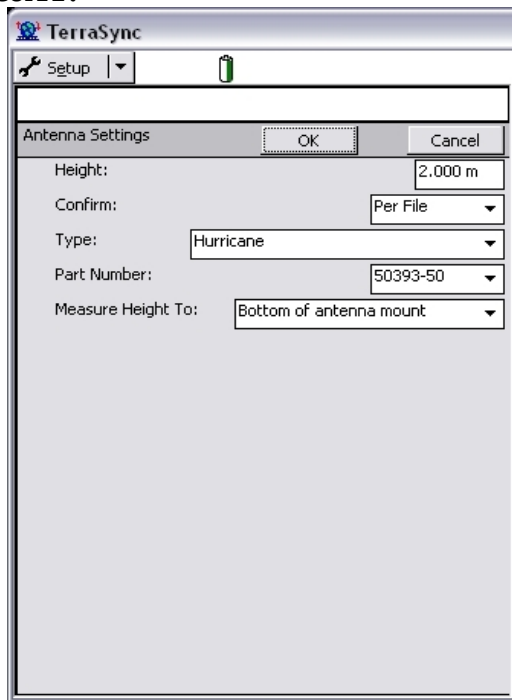


Figure 4.5. Antenna settings for the Hurricane Antenna.

2. In *GPS Settings*, change defaults to those seen in Figure 4.6. For the WICR GeoXT, *GPS Receiver Port* is COM3. If collecting data positions, set the PDOP ≥ 6.0 .

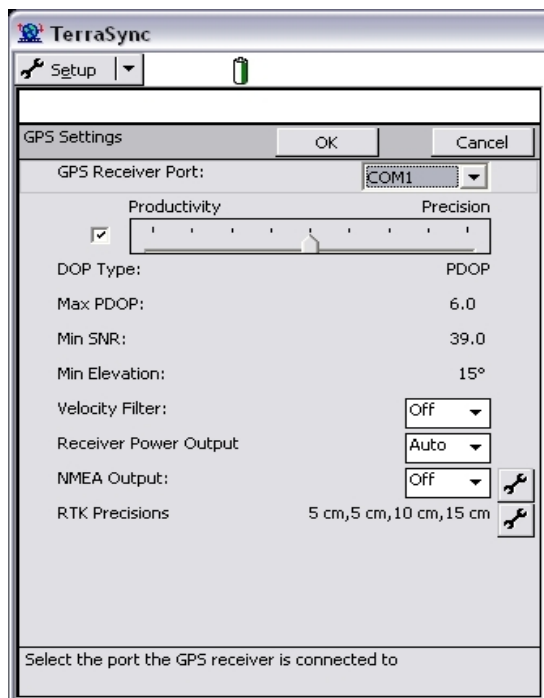


Figure 4.6. Recommended GPS settings for GeoXT.

3. The proper settings for *Real-Time Settings* depend on the GPS configuration used. If navigating using a BoB, change *Choice 1* to **External Source**. When navigating using real-time correction with the WAAS satellite differential service, set *Choice 1* to **Integrated SBAS** (SBAS includes satellite services for many different areas, WAAS is the satellites for North America). If the GPS unit is being used for data collection set *Choice 1* to the default choice, **Use Uncorrected GPS**. The setting **Use Uncorrected GPS** is used because the data that is collected will be differentially corrected during post-processing in the office by the GIS Specialist.
4. In *Coordinate System*, set the choices seen in Figure 4.7. The *Zone* will change depending on the network park location. See Table 4.1 below for correct *Zone*.

The screenshot shows the 'Coordinate System' dialog box in the TerraSync application. The dialog is titled 'TerraSync' and has a 'Setup' menu item. The 'Coordinate System' tab is active, showing the following settings:

- Select By:** Coordinate System and Zone
- System:** UTM
- Zone:** 15 North
- Datum:** NAD 1983 (Conus)
- Altitude Reference:** Height Above Ellipsoid (HAE)
- Altitude Units:** Meters
- Coordinate Units:** Meters
- Display USNG:** Off

The dialog includes 'OK' and 'Cancel' buttons at the top right.

Figure 4.7. Coordinate system choices for the GeoXT.

Table 4.1. Zones for HTLN parks.

Park	UTM Zone	Datum
AGFO	13 North	NAD 1983 (Conus)
ARPO	15 North	NAD 1983 (Conus)
BUFF	15 North	NAD 1983 (Conus)
CUVA	17 North	NAD 1983 (Conus)
EFMO	15 North	NAD 1983 (Conus)
GWCA	15 North	NAD 1983 (Conus)
HEHO	15 North	NAD 1983 (Conus)
HOCU	17 North	NAD 1983 (Conus)
HOME	14 North	NAD 1983 (Conus)
HOSP	15 North	NAD 1983 (Conus)
LIBO	16 North	NAD 1983 (Conus)
OZAR	15 North	NAD 1983 (Conus)
PERI	15 North	NAD 1983 (Conus)
PIPE	14 North	NAD 1983 (Conus)
SCBL	13 North	NAD 1983 (Conus)
TAPR	14 North	NAD 1983 (Conus)
WICR	15 North	NAD 1983 (Conus)

5. The *Units* settings should be as in Figure 4.8.

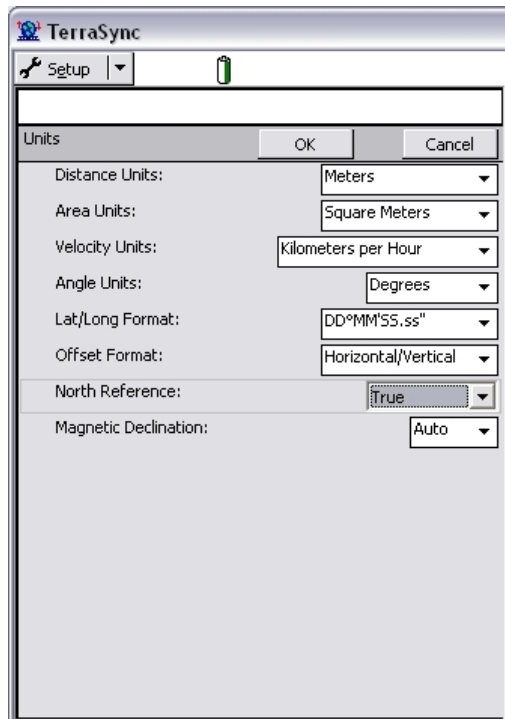


Figure 4.8. Suggested units for data collection with GeoXT.

6. All settings under *External Sensors* should be unchecked. The GIS Coordinator will have these settings already entered if they are needed. This menu is only needed if attaching a sensor or range finder to the GeoXT.

V. File Transfer

Pathfinder and Microsoft ActiveSync must already be loaded onto the PC.

1. Put the GeoXT into the charging cradle. Attach the USB cable to the charging cradle and to the connected PC.
2. After locking the GeoXT in the cradle, Microsoft ActiveSync should automatically start. When a dialog box appears, click *Guest Relationship*.
3. Once Microsoft ActiveSync is open (i.e., green) and running, open Pathfinder Office.
4. In Pathfinder Office, ensure that coordinates are set correctly for the file(s) to be transferred. To do this, click *Option/Coordinate System* and change settings as needed.
5. In Pathfinder Office, click on *Utilities* and choose *Data Transfer*. A message will appear - *Connecting to data logger*. This connection will either happen quickly or will not work due to problems with the set up. If this occurs, check the cabling and sequence of operations. Make sure that the cable is attached to the proper COM port. For the GeoXT, the proper port is *GIS Datalogger on Windows CE* (Figure 4.9).
6. Once the connection is made, check with the GIS coordinator to ensure that the source directory is correct.
7. When downloading data from the GeoXT, the *Receive* tab must be active. If transferring data onto the GeoXT, the *Send* tab should be active.
8. Next, click the *Add* button. Choose the correct file type (data, waypoint, data dictionary, etc.). You may choose more than one file at a time. When all files are chosen, click *Transfer All*.
9. When the transfer is done, click *Close* and close all programs

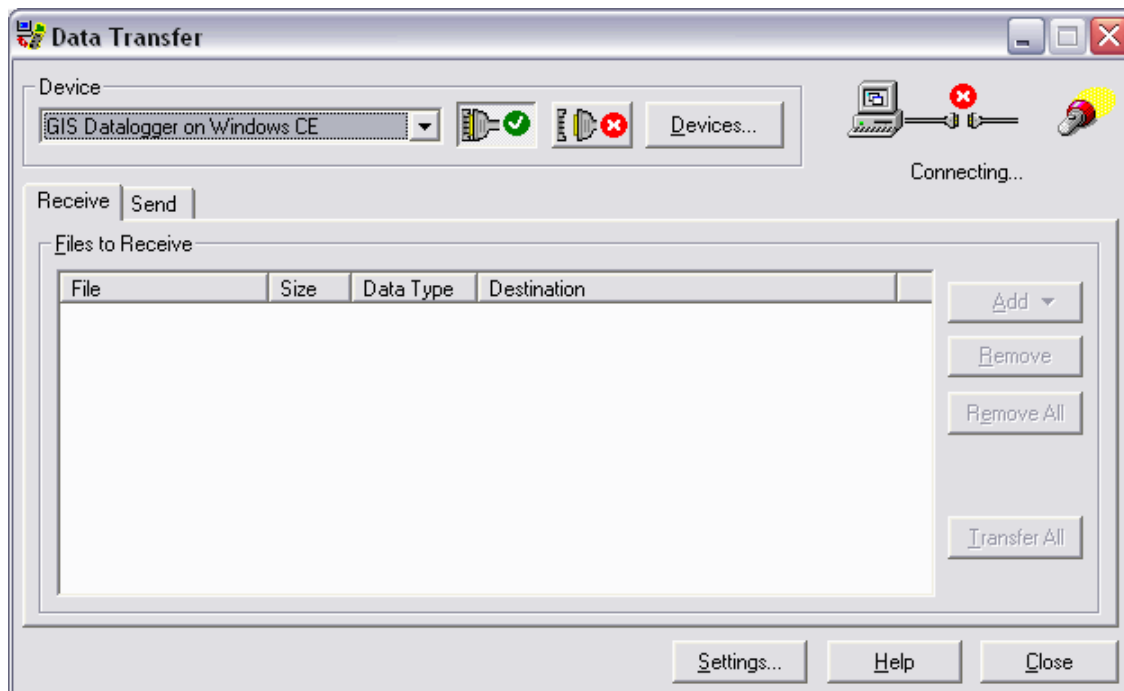


Figure 4.9. Picture of the Data Transfer window in Pathfinder Office.

VI. Data Capture

1. Open TerraSync on the GeoXT.
2. In the dropdown menu in the upper left screen corner, select *Data*.
3. If creating a new data file, select *New* in the second dropdown menu. In **File Name**, type a name with the keyboard option. Make sure the park code and the year are part of the file name. Also, select the data dictionary that you want to use in the **Dictionary Name** dropdown menu. Always keep **File Type** = *Rover* and **Location** = *Default* as the defaults. Click *Create*. If an observer re-opens an existing data file instead of starting a new one, select *Existing File* instead of *New* in the second dropdown menu. When *Choose Existing Data File* screen appears, highlight the correct file and click *Open*.
4. Click the *Options* button and select *Logging Interval* and choose *1s*.
5. Now highlight the Feature Type that you want to collect and click *Create* (Figure 4.10).
6. Fill in the blank data dictionary or the comment field if using the generic data dictionary. If the Pause icon is flashing, click the *Log* button to start collecting positions. You should now see a pencil writing and a number beside it, which indicates the number of positions collected. Collect 50 positions for each point. Number of positions for lines and polygons will depend on the size of the feature.
7. Click *OK* to finish collecting the feature.

8. To collect another feature, repeat steps 4-6. When finished, click *Close*.

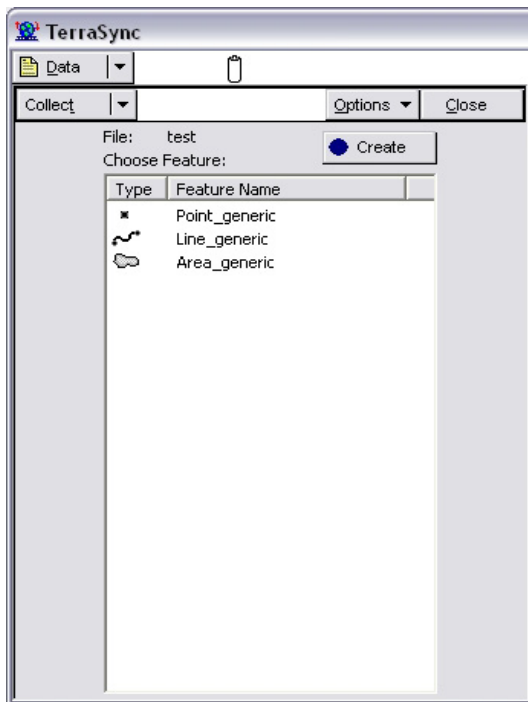


Figure 4.10. Three feature types available in TerraSync.

Special Data Capture Methods

Offsets

1. To offset a data collection point, select either *Horizontal/Vertical* or *Slope/Inclination*, which is done in the **Setup, Units** window (Figure 4.11).
2. In the **Data** window, after completing steps 1-6 in the Data Capture section, *pause* the position logging. Click *Options* and select *Offset*.
3. Depending on what offset choice was made (Figure 4.12), fill in the offset information (distance, bearing, etc.) and click *OK*. Then finish collecting the feature positions and click *OK* to finish the feature.

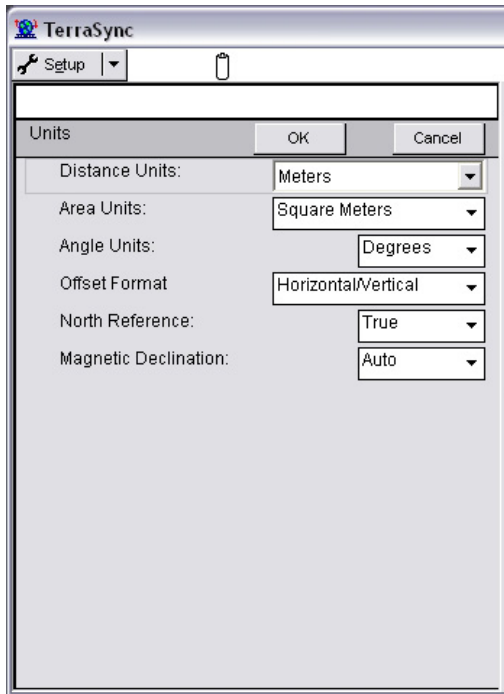


Figure 4.11. Checking offset format in the Setup<Units window.

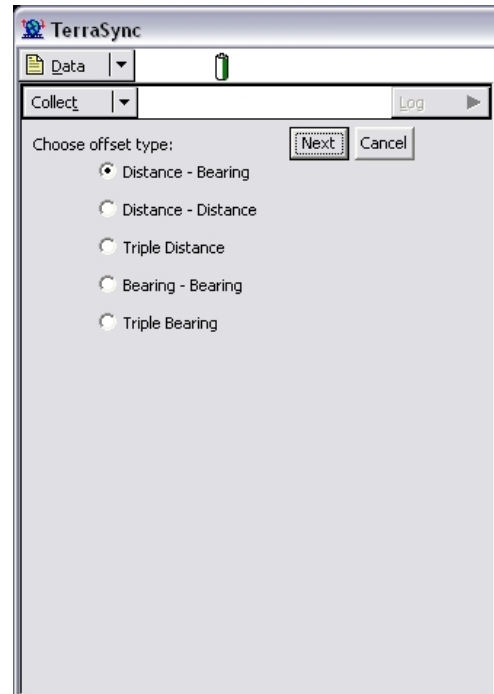


Figure 4.12. Data collection offset options.

Segmenting a Line

While in the process of collecting a segmented line, (e.g., a trail that is part gravel and part asphalt), use the Segmenting Line feature to attribute segments along the line. When an observer reaches the spot along the line where a different attribute should begin, click *Options* and select *Segment Line*. The logging positions start over and the segment can be named in the comment box. Click *OK* to complete the feature.

Continue

This function allows additional points to be added to a after closing data collection. In the Data Collection window (Figure 4.10), click *Options* and select *Continue*.

VII. Navigation

1. Open a file to guide navigation such as a waypoint file.
2. Open TerraSync and the Data window. Highlight the file of interest and click *Open*.
3. Highlight the feature of interest. Click *Options* and select *Set Nav Target*. The icon under the Name column should turn into two flags crossed over each other (Figure 4.13).
4. In the upper left hand corner dropdown box, select *Navigation*. A window appears to provide a bearing, heading, distance, and arrow that guides navigation to the selected feature.
5. To deselect the navigation target, go back to the Data window, click *Options* and select *Clear Nav Target*.

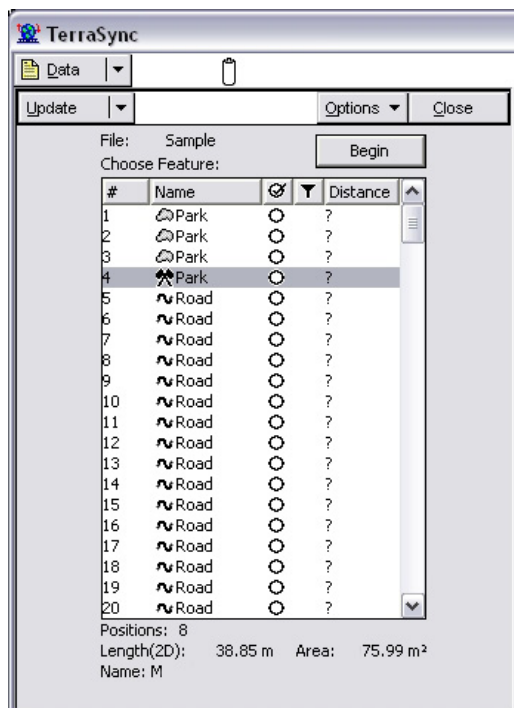


Figure 4.13. Example of crossed flags icon when feature is selected for navigation.

VIII. Map Display

Background files or data files may be displayed in the Map window. The GIS Coordinator will load files on to the GeoXT..

1. Select *Map* in the upper left hand dropdown box.
2. Click *Layers* and select *Background File*.
3. Depending on if a background or a data file is displayed, click the dropdown menu for *File Type* and select the desired type. (Data files examples: waypoint and rover files).
4. Highlight the file to display and click *OK*.
5. The file is now displayed, use the map function buttons to zoom in and out and pan (Figure 4.14).

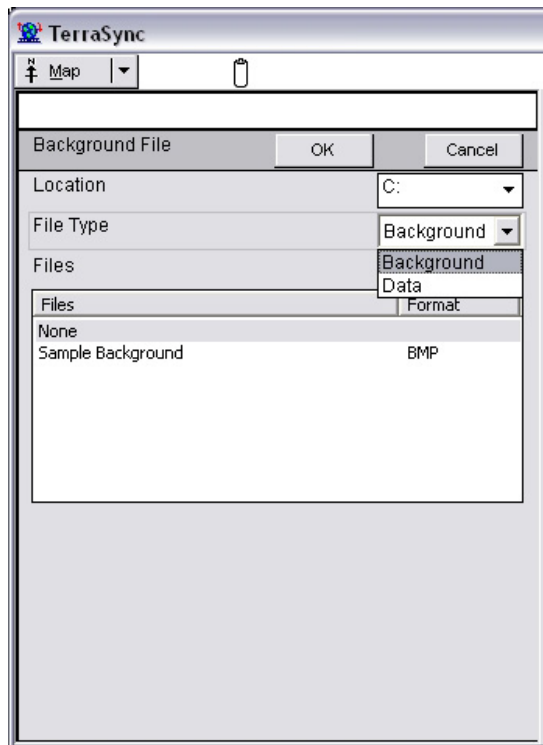


Figure 4.14. Map function buttons on GeoXT.

Entering Coordinates

If the need to hand enter coordinates occurs, the Map window is used.

1. First create or open an existing file (see Data Capture).
2. Open the Map window, click on the *Tools* dropdown menu and select *Digitize* (Figure 4.15).
3. Next click on *Options* and select *Enter Coordinates*.
4. Enter the coordinates and then click *OK* (Figure 4.16).

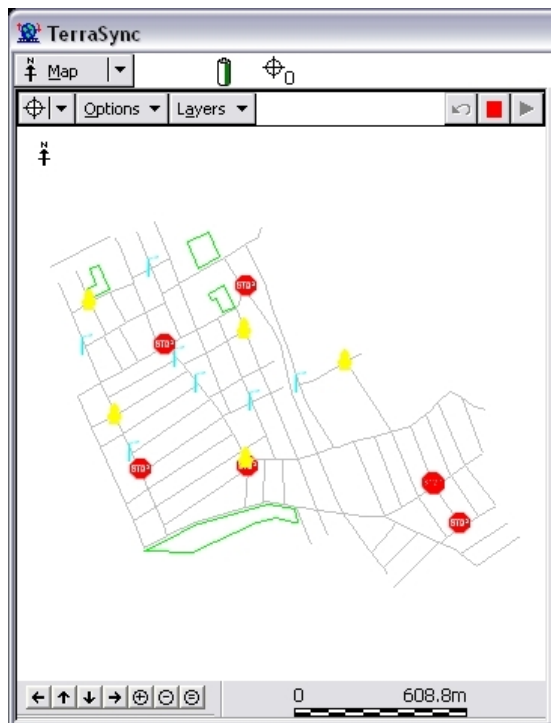


Figure 4.15. Display of the Map window with digitizing tool selected.

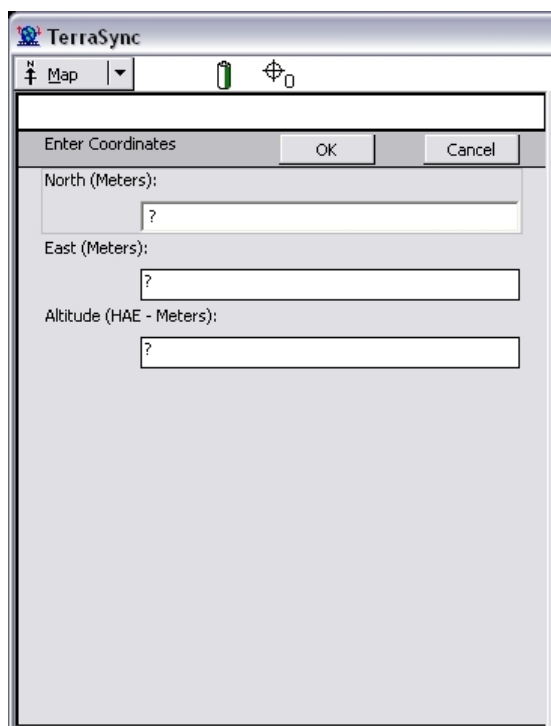


Figure 4.16. Display for entering coordinates.

Creating an Image Map Display (Figure 4.17)

This step is for displaying a raster, such as a DOQQ or an ArcMap project with multiple layers, on the GeoXT screen. When displaying the ArcMap project, it will show as just one layer and not the multiple layers that could be used to create the project.

Plain Raster File

The type of raster files that can be displayed in TerraSync are .bmp, .tif, .jpg, and .sid (GPS Pathfinder Office help). Some raster datasets cover a large area. If only small sections of the raster is needed, clip the image in either ArcGIS or ERDAS Imagine to save space on the GPS unit. Remember a world file is needed with every raster file loaded onto the GPS unit. For help on creating a world file, see the GPS Pathfinder Office help index.

ArcMap Project Display

1. Create a project in ArcMap.
2. In the printer setup selection choose: Microsoft Office Document Image Writer.
3. In the layout display, fit the data frame to margins. Note: Do not add legend, north arrow, etc. to the layout.
4. Export the layout as a .tif with 300 dpi.
5. If the image needs to be cropped, use Adobe Photoshop.
6. Bring the newly created .tif file into ArcMap and rectify it using the Georeferencing toolbar. By rectifying the .tif in ArcMap, a world file is automatically created.
7. Transfer the .tif file to the GPS unit.

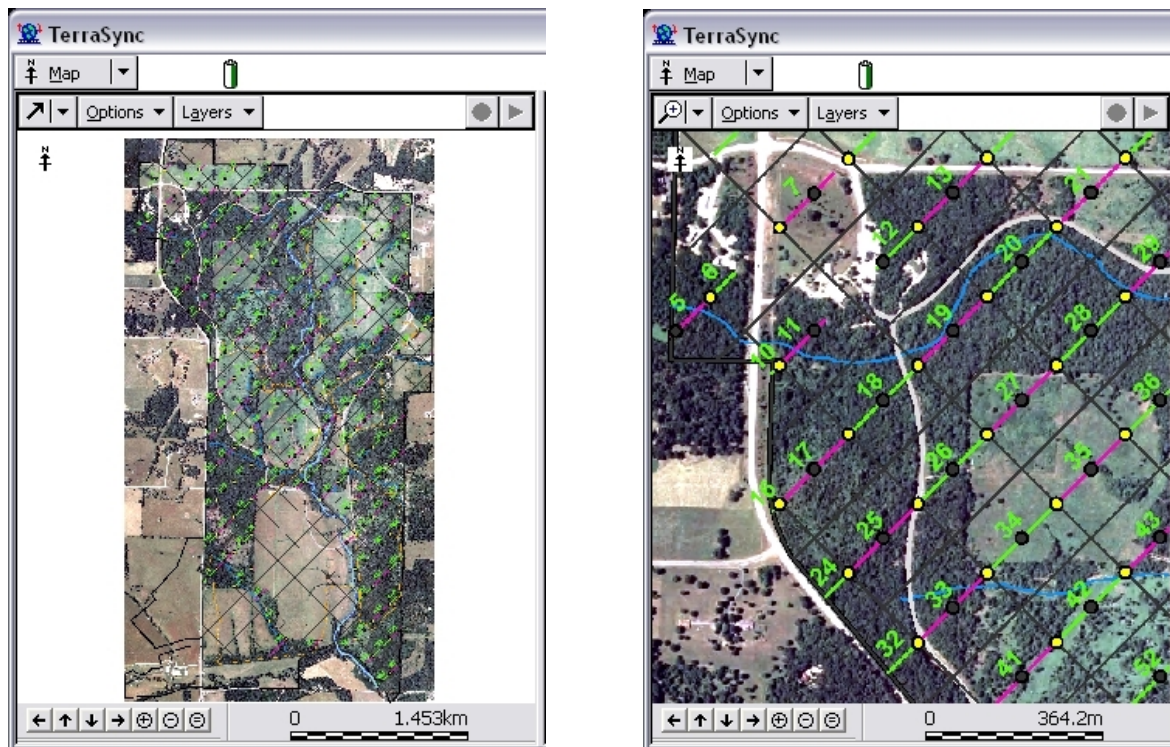


Figure 4.17. GPS map displays from an ArcMap project.

IX. Differential Correction

Differential correction is performed using Pathfinder Office software after the rover file is transferred to the desktop computer. Prior to correcting the file, ensure that the coordinate system is correct.

1. Click on *Utilities*, choose *Differential Correction*.
2. Browse for the rover file that requires correction.
3. Click *Internet Search, New*.
4. Select *Copy the most up-to-date list from Trimble's Internet site*, select suitable base station files and, click *OK*. Under confirm setup, click *Yes*.
5. Highlight the base provider that is closest to the data collection site and that has a high integrity index. Write down the base provider information so that it can be put in the metadata later. Click *OK*.
6. When a base provider of the same name already exists, the message "Overwrite existing base provider?" is generated. Click *Yes*.
7. On *Provider Properties*, click *OK*.

8. In the Confirm Selected Base Files box, click *OK* if coverage is 100%. If not repeat steps 5-7, with the next closest base station provided until 100% coverage is attained.
9. For *Reference Position*, use default values and click *OK*.
10. Make sure the output folder is correct. Click *OK*.

X. Exporting Rover Files as Shapefiles

1. Check to see if the coordinate system is correct.
2. In Pathfinder Office, click on *Utilities*. Choose *Export*.
3. Browse to the file that needs to be exported. Make sure that the output folder is correct. Click the *Properties* button. Then click the *Attributes* tab. The following should be checked: **All Feature Types** – PDOP, Correction Status, Receiver Type, Date Recorded, Time Recorded, Update Status, Data File Name, Filtered Positions, Data Dictionary Name; **Line Features** – Length (2D), Average Horiz. Precision, Worst Horiz. Precision; **Point Features** – Horizontal Precision, Standard Deviation, Position; **Area Features** – Area (2D), Average Horiz. Precision, and Worst Horiz. Precision. Click *OK*. Click *OK* again in the Export box once everything is set.
4. After a shapefile is exported, rename that file right away in ArcCatalog. The default is a generic name such as point_ge or the name from the data dictionary. If exporting more than one file, the previous file will be overwritten. To avoid such overwriting, rename each file after each export.
5. After the shapefile is successfully exported, open ArcToolbox. Scroll to Data Management Tools; Projections and Transformations, and click on *Define Projection*. Browse to the file and set the coordinate system used to collect the feature.
6. Using ArcCatalog, create metadata for the file.

XI. Troubleshooting

Inevitably, observers are likely to encounter problems using the GeoXT GPS unit. In some cases, PDOP may be inadequate to support data collection. When troubleshooting, check the battery power and the assembly of the unit. Toggling too fast between screens may cause the unit to lock up. If the unit does not self-correct within a couple of minutes, perform a hard restart by holding the power button down for 15 seconds. Data that are not backed up may be lost. If the TerraSync installation code is ever required, this number is located on the case by the handle and also on a card inside the case. Type the number into the unit with dashes.

Keep track of the problems that occur for each GPS unit. Use *Problem Log* sheets (Appendix 4C). Fill out as much information as possible, such as user, date, unit number,

steps taken before problem, error message, etc. This sheet is filled out and given to the GIS coordinator.

XII.

Appendix 4A. Glossary of Terms Critical to Using a GPS Unit

Elevation Mask: Sets cut-off elevation for satellites. The unit will not gather positions from satellites lower than the degree set. This should be a minimum of one degree above the Base Station Mask with 15 degrees recommended. This is most important during the planning stages. When working in locations with obstructions, the mask may be set higher so that only those satellites higher in the sky will be used for data collection. These situations may also be evaluated by checking the azimuth position of satellites in Quick Plan.

SNR Mask: Signal strength or Signal to Noise Ratio. If SNR Mask is too high, data quality is diminished. The range is 0-99. If the SNR mask is raised, more satellites may be used, but the data is not as good.

PDOP Mask: Position Dilution of Precision. PDOP is an indication of the accuracy of the calculated position based on the location of the satellites in the constellation. If satellite positions do not allow the use of coordinate geometry, then accurate ground locations can not be triangulated from them. Less than 4 = very good; 5 to 8 = adequate; more than 8 = stay home.

Julian Date: Day of the year between the range of 1 and 365. For example, the Julian Date for February 2 is #33. February 2 is the calendar date.

Feature: The units for which data are collected. Examples include buildings, woodlots, roads, trails, points, etc.

Attributes: Descriptive characteristics of features.

Points, Lines, and Polygons: Geographic terms related to scale that describe how features are drawn. Points are single dimensional, lines have length, and polygons have area.

Position(s): The number of signals received from the satellites that are used to make the GPS features. For point features collect 50 positions. Number of positions will vary for lines and polygons.

Differential Correction: Increases the accuracy of the data files by correcting errors associated with the signal received from the satellites. Also call post-processing. (See Pathfinder Office help – differential GPS).

BoB: Beacon-on-a-Belt is a real time correction receiver.

The F2 button on the GeoXT unit displays the battery power.

Appendix 4B. GeoXT Icons



Real-time WAAS: The GPS is picking up real-time corrections from WAAS satellite.



Real-time BoB: The GPS is picking up real-time correction from the Beacon-on-a-Belt.



Battery power for the GPS.



Shows that the GPS is logging positions. The number is the amount of positions.



Digitizing: For drawing features or entering coordinates.



Data window.



Map window.



Navigation window.



Setup window.



Status window.



Real-time beacon: The GPS is able to receive real-time correction data from a beacon or base station.



Connection: The icon is showing no connection, when the two pieces are together there is a connection. This icon is seen when connecting the GPS to a computer in Pathfinder or when connecting the handheld unit to its GPS receiver.



Features: The three different feature types that can be collected with the GPS unit. In order from top to bottom; point, line (arc), and polygon.



Pause: When collecting positions for a feature you may pause the collection process.



Satellites: Number of satellites the GPS is able to connect to and receiver position data.



WAAS: Where the WAAS satellite is located in the skyplot. In newer versions of TerraSync may be called SBAS. WAAS is a real-time correction satellite.

Appendix 4C. GPS Problem Log

Date:

GPS unit:

User:

Park:

Problem/Error message:

Steps taken before problem occurred:

**Invasive Exotic Plant Monitoring Protocol
Heartland Network I&M Program**

Standard Operation Procedure 5: Exotic Plant Prioritization Database (PriorityDB)

Version 1.00 (7/1/2007)

Revision History Log:

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

I. Purpose

PriorityDB provides four key data elements:

- 1) a list of regional exotic plant species (based on numerous state and national lists)
- 2) a list of exotic plants in each state (based on USDA Plants database and state lists)
- 3) a list of exotic plants in each park (based on NPSpecies database)
- 4) a designation of exotic plants as high priority (i.e., invasive exotic plants) based on a consensus of the state and regional lists.

II. Exotic Plant Prioritization Database MS Access Table Development

The exotic plant prioritization database (PriorityDB) is an MS Access database that consists of six tables.

Table 1: tbl_USDA_Plants (Figure 5.1)

This table, tbl_USDA_Plants, provides a list of all current accepted and synonymous vascular plant taxa for the United States per the Integrated Taxonomic System (ITIS), the national standard for taxonomic information. The table can be downloaded from the following website: http://plants.nrcs.usda.gov/cgi_bin/topics.cgi?earl=dl_all.html. The table is downloaded as a comma delimited text file and then brought into Access using the File: Get External Data function. When downloading the table, follow these procedures:

1. Use default settings
2. Check
 - a. State distribution
 - b. Symbol
 - c. Accepted names and synonyms

- d. Common name
- e. ITIS TSN

Symbols are alphanumeric codes that identify all taxa in USDA Plants. Note that the **symbol key** field lists the currently accepted symbol for all taxa (accepted and synonymous). The **synonym symbol key** field only lists the symbol for synonymous taxa. The **symbol** field lists the symbol for accepted and synonymous taxa. Because the symbol field does not contain duplicates and includes a symbol for every record, this field best serves as a primary key for the table. Collectively, these three fields can be used to develop queries that differentiate between accepted and synonymous taxa. The TSN (taxonomic serial number) field is indexed and allows no duplicate entries, which allows for creation of relationships with referential integrity as needed. TSNs are only available for currently accepted taxa.

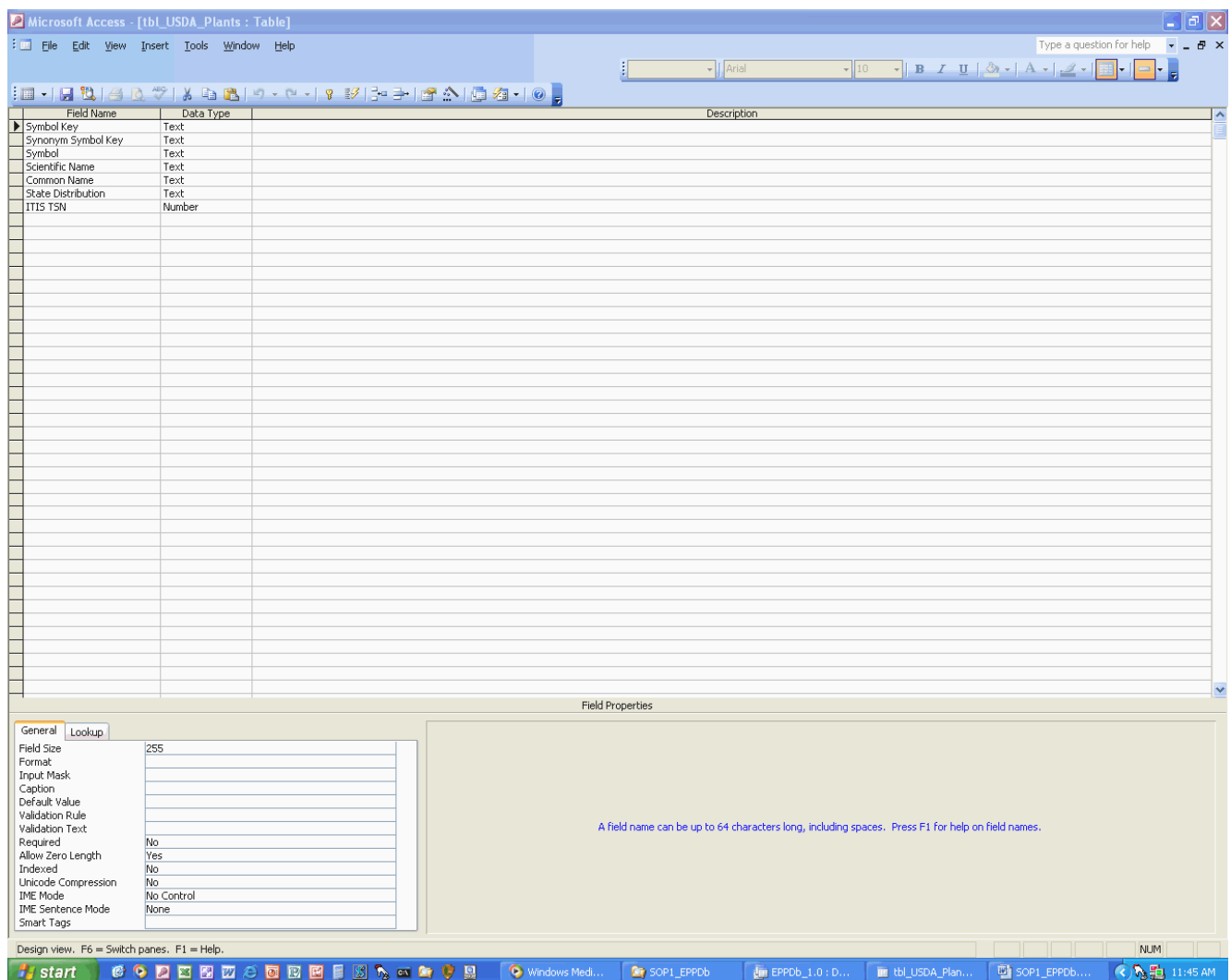


Figure 5.1. tbl_USDA_Plants

Table 2: tbl Regional ExoticPlants (Figure 5.2)

This table, referred to as the **regional exotic plant list**, synthesizes information from fifteen lists in an attempt to find a consensus on exotic plants that are likely to be problematic in natural areas of network parks.

The following lists were consulted:

1. Missouri Vegetation Control Manual by the Missouri Department of Conservation (<http://www.mdc.mo.gov/nathis/exotic/vegman/>).
2. Illinois Native Plant Society List (<http://www.inhs.uiuc.edu/inps/exotics.htm>).
3. Invasive Plants Association of Wisconsin Working List (<http://www.ipaw.org/newsletters/issue4.pdf>).
4. Invasive Plants in Arkansas' Natural Areas, a tentative list obtained from Theo Witsell, Arkansas Natural Heritage Program.
5. Nonnative Invasive Plants of Southern Forests by James H. Miller, United States Forest Service (<http://www.invasive.org/eastern/srs/>).
6. Nebraska watch list of plants that are highly invasive and difficult to control by Nebraska Weed Control Association (<http://www.neweed.org/watchlist/wlindex.htm>).
7. Minnesota Department of Natural Resources (<http://www.dnr.state.mn.us/invasives/index.htm>).
8. Ohio's Top Ten Invasives (<http://www.dnr.state.oh.us/dnap/invasive/invasivebrochure.htm>) and exotic plants with factsheets (<http://www.dnr.state.oh.us/dnap/invasive/>).
9. Invasive Plants in Indiana, a joint publication of the of Indiana Department of Natural Resources, The Nature Conservancy, Indiana Native Plant Society, United States Forest Service, Indiana Academy of Science (<http://www.inpaws.org/InvasivePlants.pdf>).
10. Missouri Exotic Pest Plant List from the Missouri Botanical Garden (<http://www.mobot.org/MOBOT/research/mepp/ratings1.html>). Ranks A-D.
11. Plant Conservation Alliance list for plants occurring in AR, IA, IL, IN, KS, MO, MN, NE, OH (<http://www.nps.gov/plants/alien/list/all.htm>).
12. NatureServe's Data on U.S. Invasive Species: Impact Assessments with Invasive Ranks (I-Ranks) (<http://www.natureserve.org/explorer/>).
13. Invasive Plants of the Upper Midwest by E.J. Czarpata, 2005. Ranks: A=major concern, B=lesser concern, C=potential concern.
14. Invasive Plants in the Chicago Region from the Chicago Botanic Garden: (http://www.chicagobotanic.org/research/conservation/invasive_chicago.html). Ranks: E=evaluate, R=remove, P=phase-out, W=watch list.
15. New invasive plants in the Midwest list from the Midwest Invasive Plant Network (www.mipn.org).

Taxa information was entered directly into the table for all plants on each list with the exception of list 12. In this case, I-ranks were only attributed to plants included on at least one other list.

In order to ensure that current taxonomy was used, the species included on the lists were compared against names in `tbl_USDA_Plants`. Provided that a TSN was given (TSNs are only listed for accepted taxa), the symbol, scientific name, and TSN were all entered manually in

tbl_Regional_ExoticWeeds. The absence of a TSN indicated that the taxon is a synonym or that USDA Plants has not yet assigned a TSN to the taxon. If the taxon is a synonym, the accepted taxon symbol was listed in the symbol key field. The information from the record with that symbol in the symbol field was then entered in the table. If the entries in the symbol key and symbol fields match and a TSN is not given, then a TSN has not yet been attributed to the taxon, although the taxon is accepted. In this case, the older taxonomy that includes a TSN was entered, the Updated_USDAPlants field was checked as an indicator that outdated taxonomy was used, and the accepted taxon was entered in the Updated_Name field. Outdated taxonomy is used in this case to ensure that a TSN is available for compatibility with NPSpecies, which uses TSN as its primary key. If a TSN can still not be found using these approaches, a temporary number between 1 and 100 was entered in the TSN field. Taxa with temporary TSNs are generally not available in queries and must be entered on to appropriate watch lists manually. As of April 2007, a single species was assigned a temporary TSN.

The objectives and process for developing each exotic plant list are not always apparent. Taken as a whole, we surmise that the lists were based on existing lists of plant pests, experience from a range of resource management disciplines, consensus of groups dedicated to managing exotic plants, as well as more objective processes that involved thorough research, interview of experts, and carefully documented ranking processes (e.g., Invasive Plants Association of Wisconsin Working List and NatureServe's Data on U.S. Invasive Species: Impact Assessments). While lists were sought for each state and important lists were found, additional lists are likely to exist that may be helpful.

The designation of an exotic plant as a high priority (i.e., an IEP) species is based on a consensus of the various lists. All plant species with an I-rank of H and all plants on the early detection oriented New Invasive Plants in the Midwest list were marked as a high priority. Beyond these lists, the high priority designation was reserved for exotic plants included on a number of lists with some caveats. The Invasive Plants in Arkansas Natural Areas list and Nonnative Plants of Southern Forests list were given greater consideration because only these lists cover many of the IEPs with southern affinities. The I-rank was also considered strongly in high priority designations. Although the prioritization is subjective, this approach offers several advantages: 1) the decision is based on multiple lists and does not rely on any single listing or ranking approach, and 2) the decision does not use a scoring system in an attempt to make a subjective approach seem more objective. Rather, this system supposes that priority designation will be revisited and modified over time based on new information, but assumes that a core of the most problematic plants will continue to be designated as high priority IEPs.

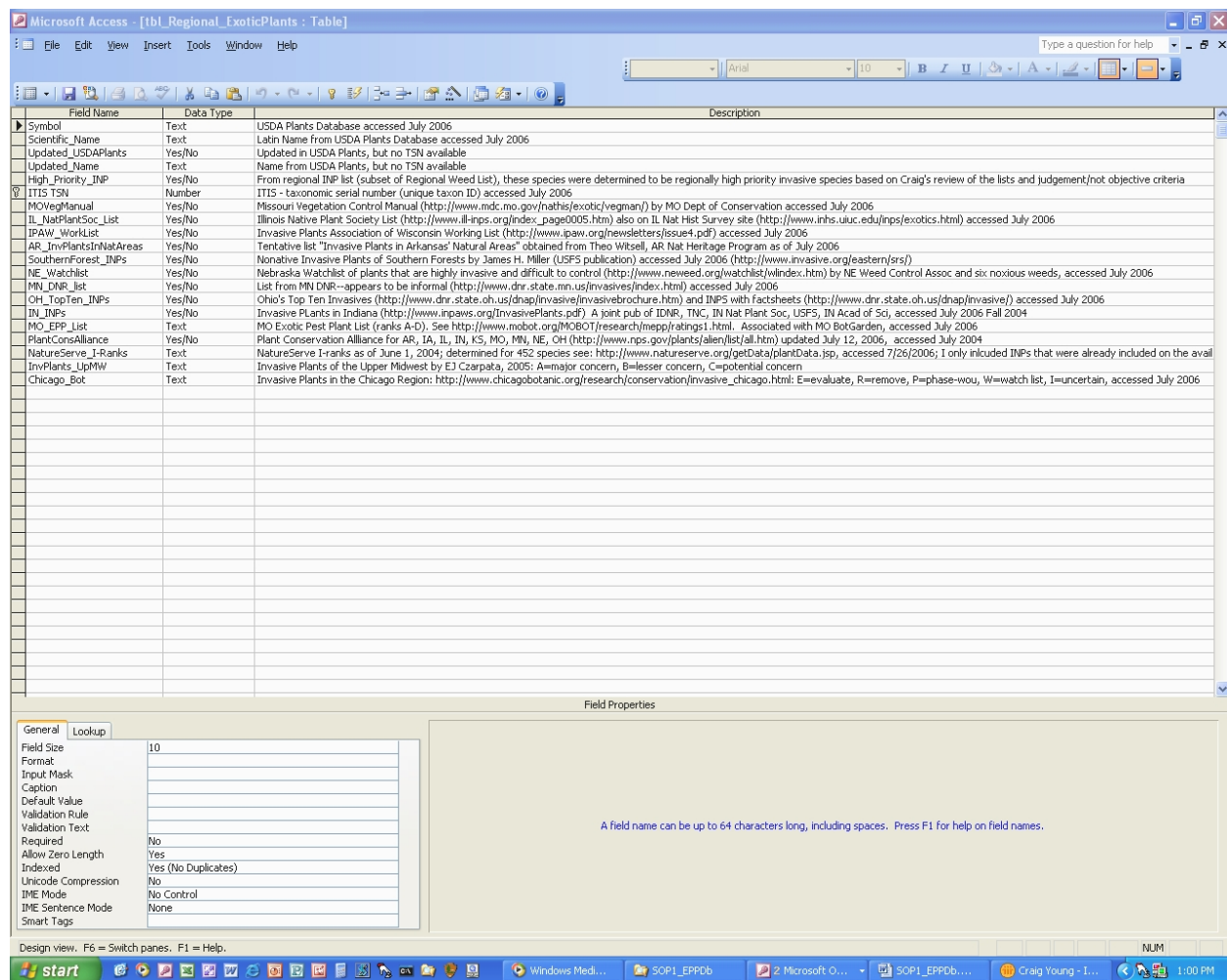


Figure 5.2. tbl_Regional_ExoticPlants

Table 3: tbl_NPSpecies (Figure 5.3)

NPSpecies (<https://science1.nature.nps.gov/npspecies/>) is a national NPS inventory and monitoring database that serves as the standard for documenting species occurrences on NPS park units. Data for all species occurrences can be downloaded in MS Access format for each park using the Utilities:Download function in NPSpecies. The tables are then amalgamated in a step-wise fashion using the Append Query function.

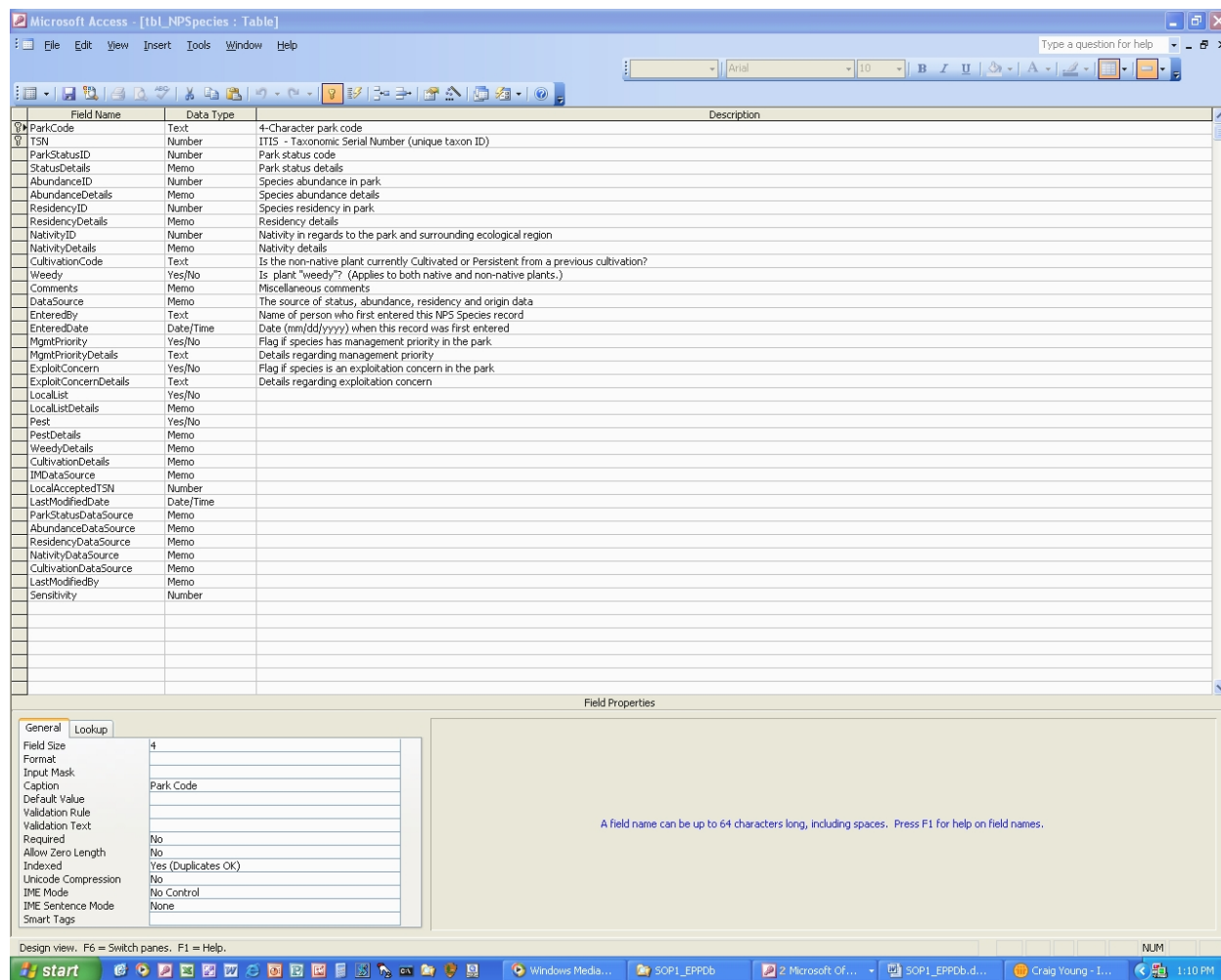


Figure 5.3. tbl_NPSpecies

Table 4: tbl_NPSpecies Nativity (Figure 5.4)

This table is a look-up table from NPSpecies that explains the codes used to specify nativity of species found in parks.

Table 5: tbl_NPSpecies Taxonomy (Figure 5.5)

This table is a look-up table from NPSpecies that includes the taxonomic information (genus and species) associated with each TSN.

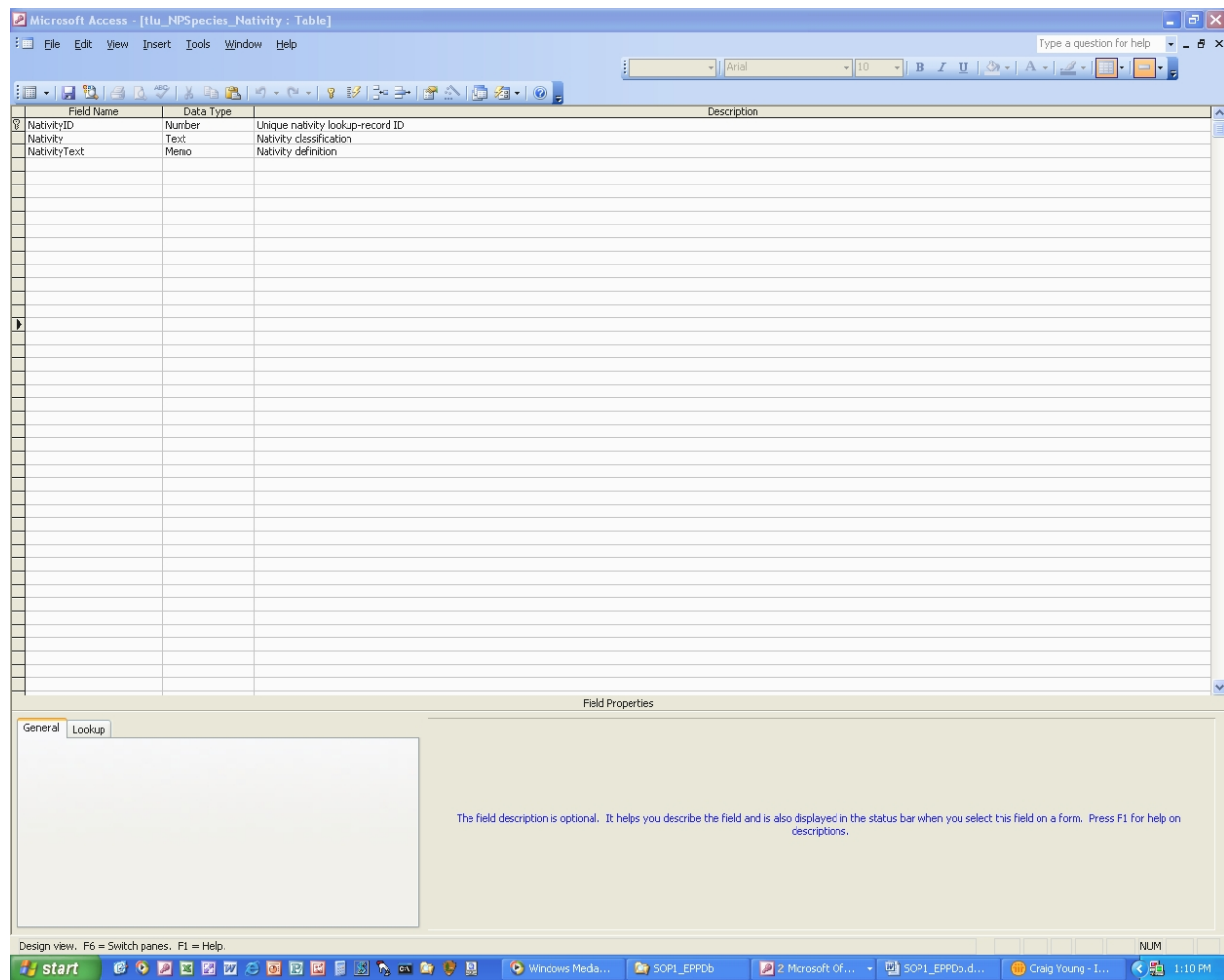


Figure 5.4. tbl_NPSpecies_Nativity

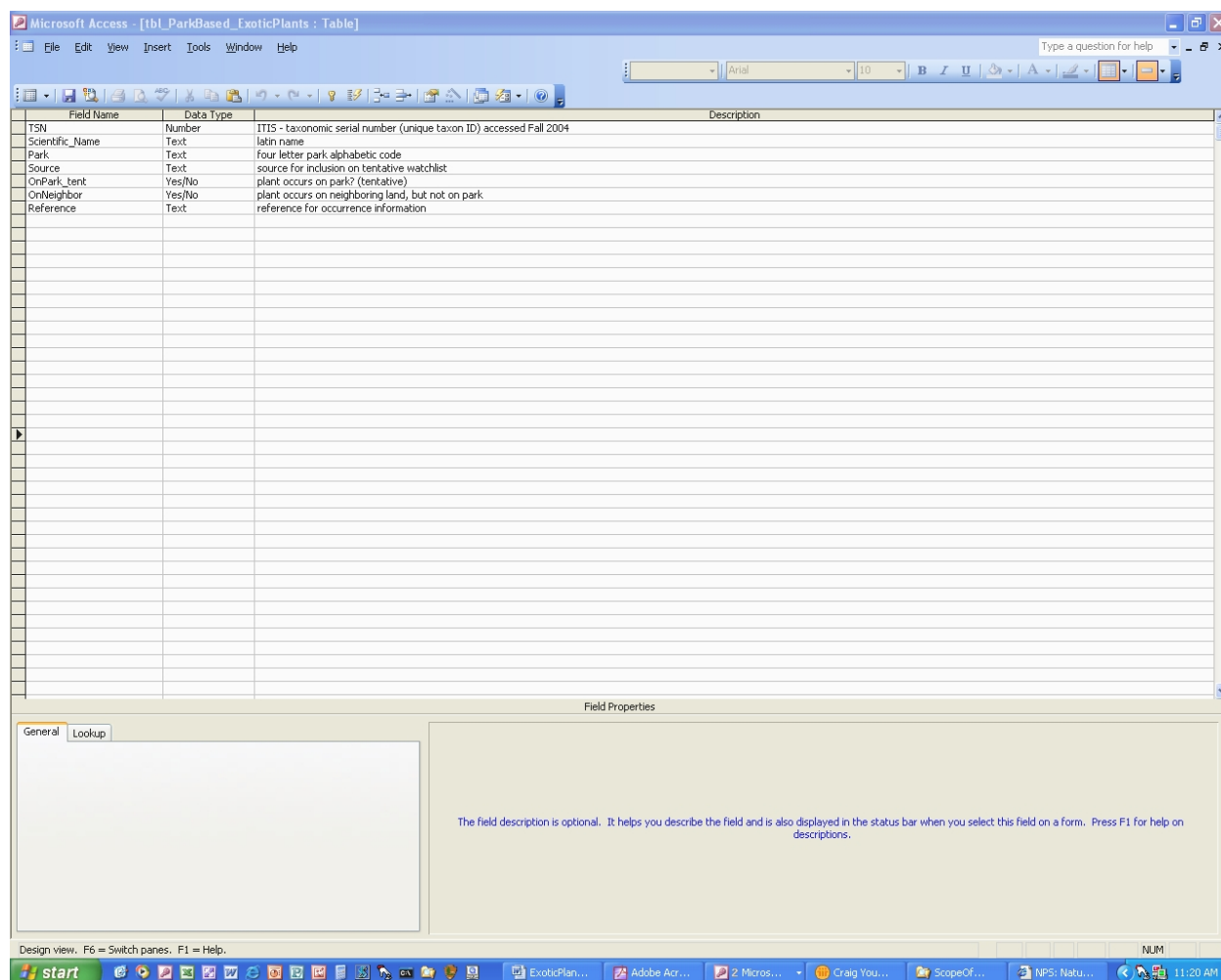


Figure 5.5. tbl_NPSpecies_Taxonomy

Table 6: tbl_ParkBased_ExoticPlants (Figure 5.6)

This table, referred to as the **park-based exotic plant list**, contains data that may have been missed from the regional exotic plant list or NPSpecies. Information is entered in this table on a park-by-park basis. For example, NPSpecies may not document a plant as occurring on a park, although a park manager knows or suspects the plant to occur on the park. Alternatively, USDA Plants state distribution information may be inaccurate or incomplete. Finally, a park manager may wish to monitor an exotic plant that is not included on the regional exotic plant list. Such adjustments should be recorded in this table rather than attempting to directly update the other tables. As the other tables are normally updated and verified through defined processes (NPS updates NPSpecies; USDA updates USDA Plants), we expect that provisional data in the park-based exotic plant list will enter the other database tables during periodic updates. The table also allows managers to enter data about plants known to occur on adjacent lands. These species may be added to the early detection watch list as they are the most likely invasive exotic plants to become established on the park.

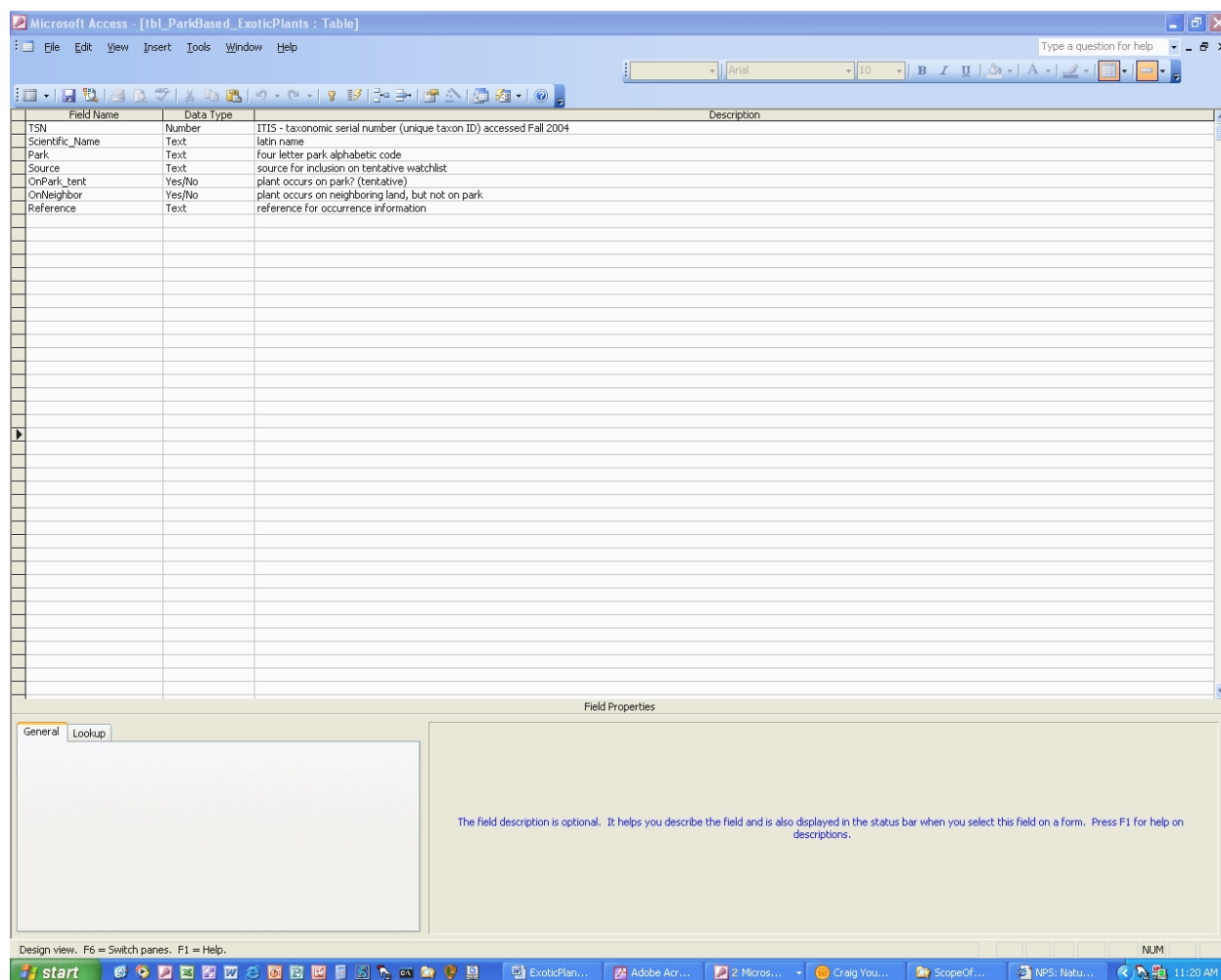


Figure 5.6. tbl_ParkBased_ExoticPlants

III. Exotic Plant Prioritization Database Query Development

Using the six tables, three *types* of queries generate two exotic plant watch lists for each park: 1) an early detection watch list and 2) a park-established watch list.

Type 1 query: qry_State [StateCode] (Figure 5.7)

This query generates the list of exotic plants of concern that are found in each state where a network park is located (AR, IA, IN, KS, MO, MN, NE, OH). All lists include high priority plants (based on tbl_Regional_ExoticPlants) known to occur in states with network parks (based on tbl_USDA_Plants). For six states, the query also included all species from selected state lists, regardless of their designation as a high priority plant. For example, all species from the Missouri Vegetation Control Manual and A-ranked species from the Missouri Botanical Garden list were also included for the Missouri list. An example type 1 query for Missouri is shown in Figure 5.7.

Because a TSN is unavailable for some accepted taxa, outdated synonymous taxa were included on the regional exotic plant list when needed to secure a TSN. However, state distribution information is not provided for synonymous taxa. As a result, the query includes a link between symbol and symbol key to obtain state distribution data for these synonymous taxa. The state distribution of species assigned a temporary TSN must be checked and added manually.

Type 2 query: qry_ParkEst [ParkCode] (Figure 5.8)

This query generates the list of plants from the qry_State_[StateCode] known to occur on network parks (based on tbl_NPSpecies). An example type 2 query for George Washington Carver National Monument is shown in Figure 5.8. The occurrence of species assigned a temporary TSN in network parks must be checked and added manually.

Type 3 query: qry_Lists [ParkCode]

For each park, type 3 queries provide two side-by-side lists to carry in the field: a comprehensive list of exotic plants of concern for each park and a list of plants known to occur on each network park based on type 1 and 2 queries. The plants that occur exclusively on the first list constitute the early detection watch list. The species on the second list constitute the park-established watch list. Note that the query uses a left join. Also, note that the early detection list qry_ParkEst_[ParkCode] may include fewer species than are found on qry_Lists_[ParkCode] because USDA Plants does not recognize a plant as occurring in the respective state. The excluded species should be added to the park-based watch list (tbl_ParkBased_ExoticPlants). An example type 3 query for George Washington Carver National Monument is shown in Figure 5.9.

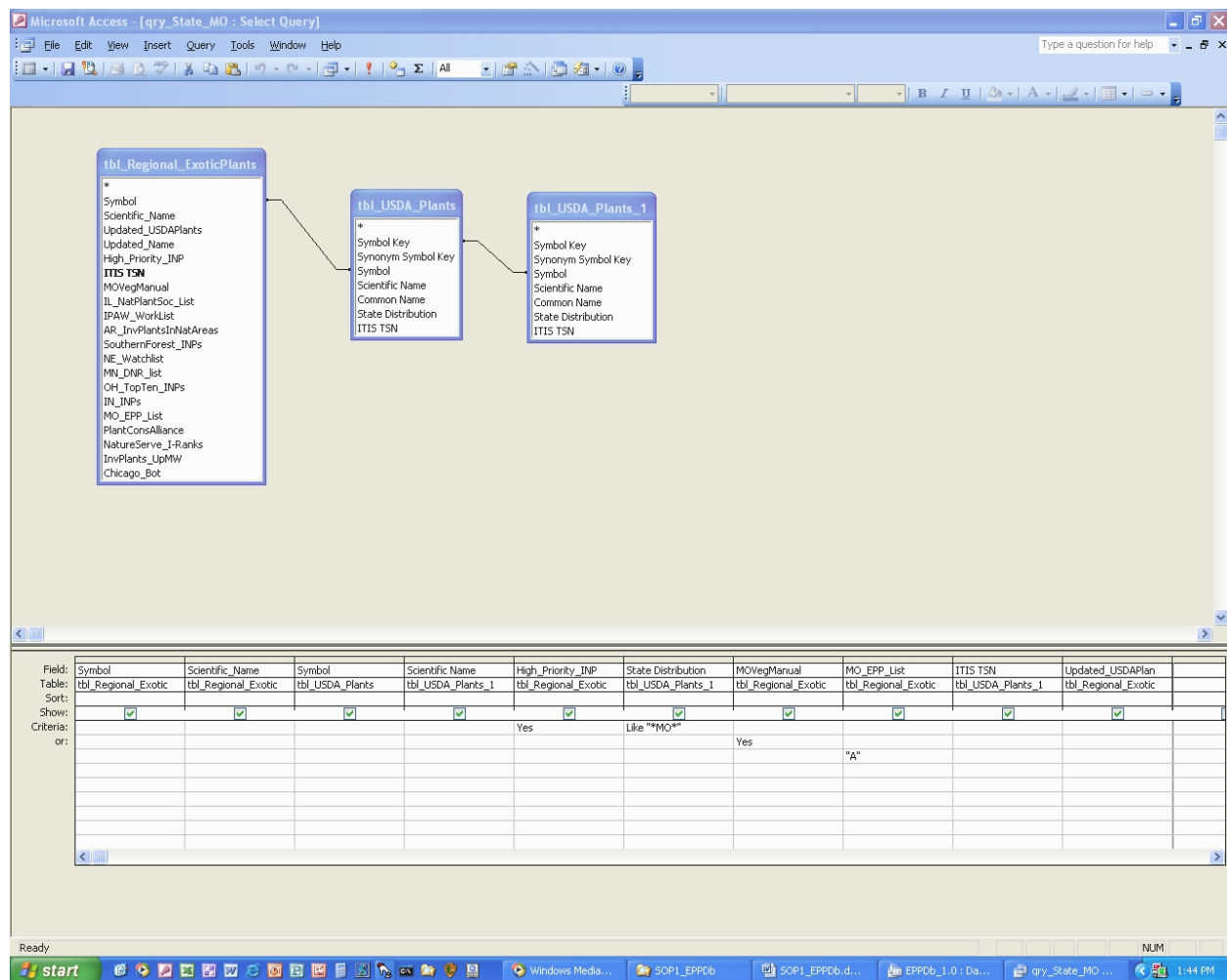


Figure 5.7. qry_State_MO

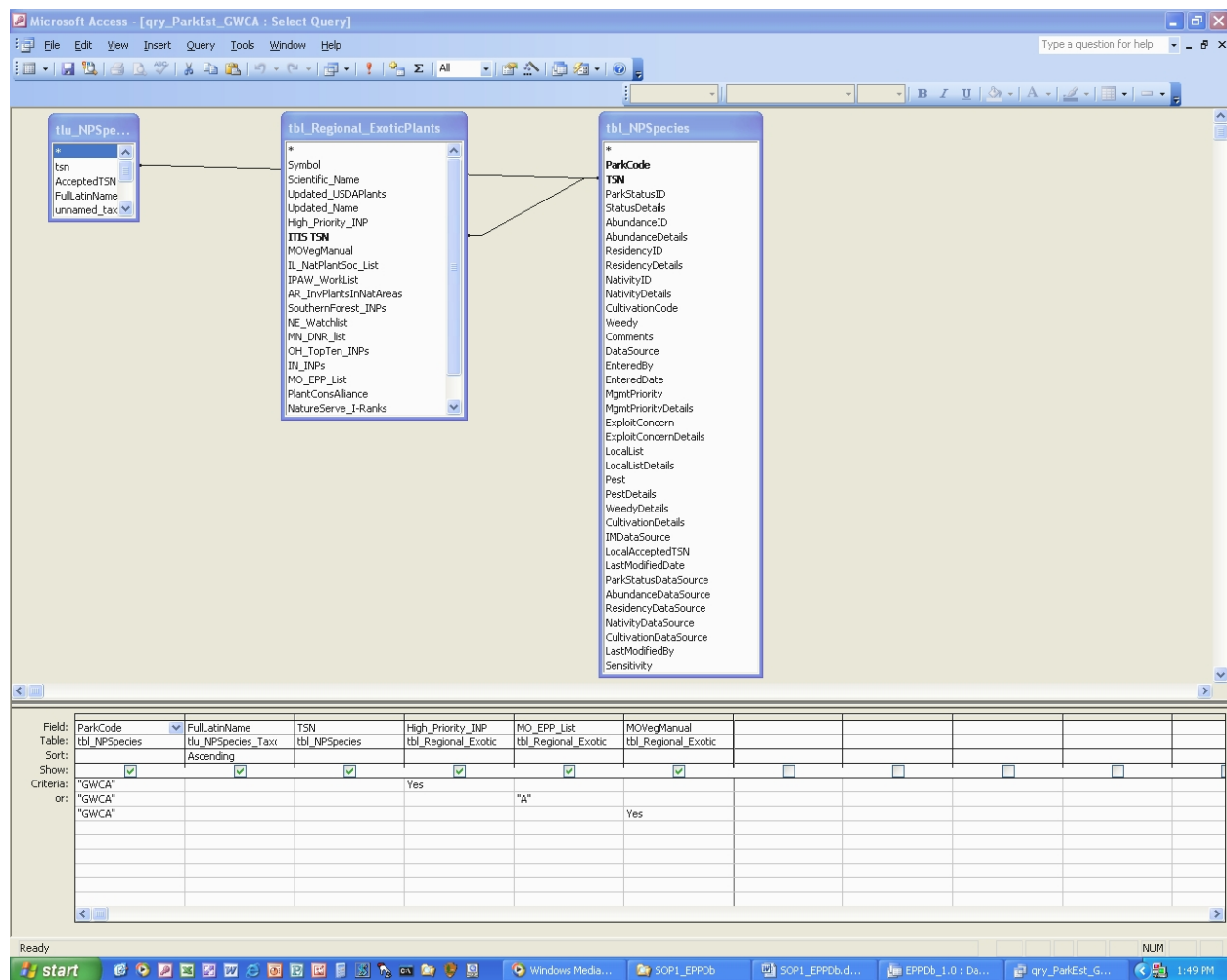


Figure 5.8. qry_ParkEst_GWCA

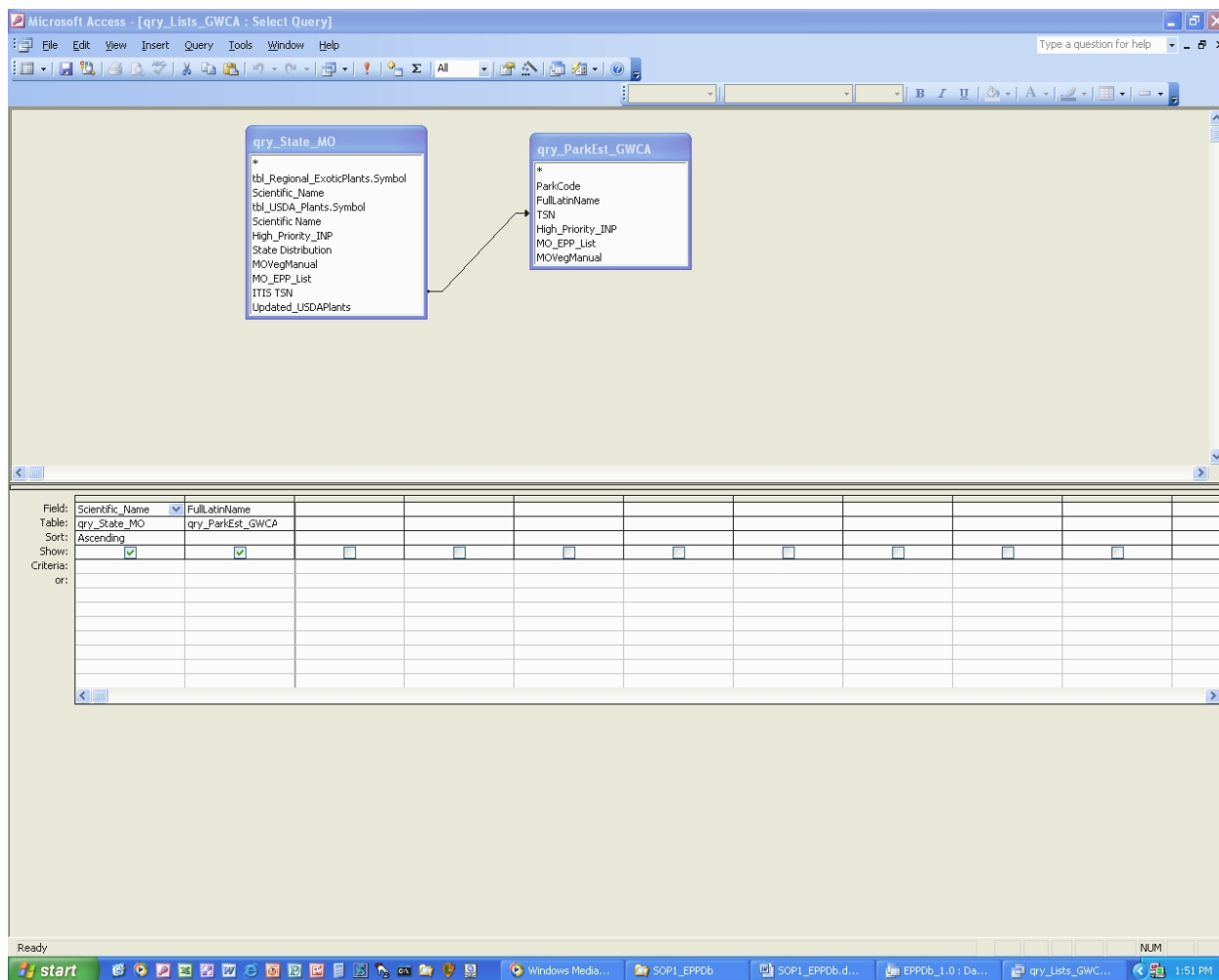


Figure 5.9: qry_Lists_[ParkCode]

IV. Exotic Plant Prioritization Database Validation Queries (Figures 5.10, 5.11)

Two queries are designed to validate data compatibility between the regional exotic plant lists and the USDA Plants database and the NPSpecies database. The query, valqry_RegionalExotics_To_USDAPlants, ensures that all plants included on the regional exotic plant list (tbl_Regional_ExoticPlants) are assigned a TSN which is associated with a corresponding TSN on the USDA Plants list (tbl_USDA_Plants). The query, valqry_RegionalExotics_To_NPSpecies, ensures that all plants included on the regional exotic plant list (tbl_Regional_ExoticPlants) are assigned a TSN which is associated with a corresponding TSN on the NPSpecies taxonomy list (tbl_NPSpecies_Taxonomy) (Figure 5.10).

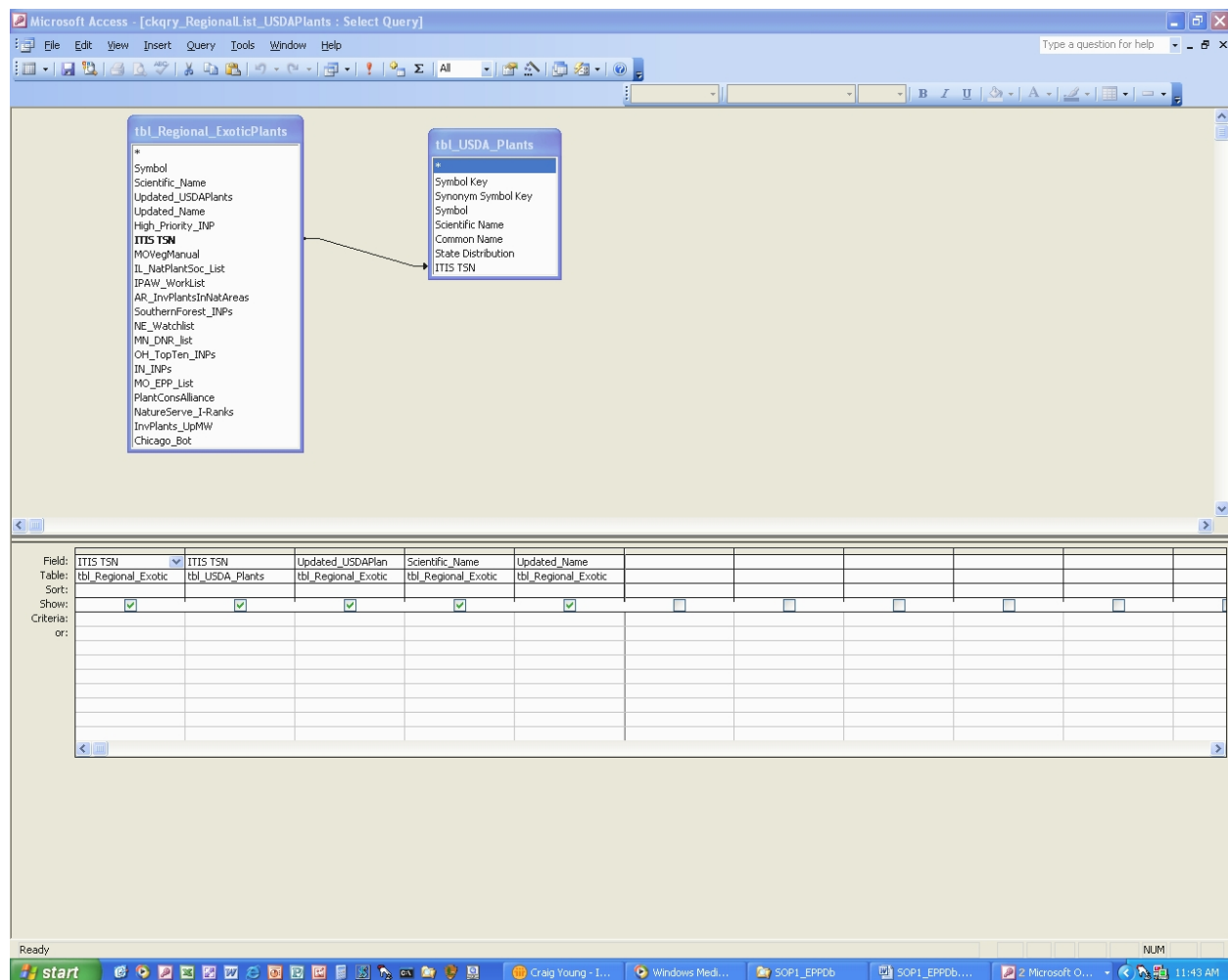


Figure 5.10. valqry_RegionalExotics_To_USDAPlants

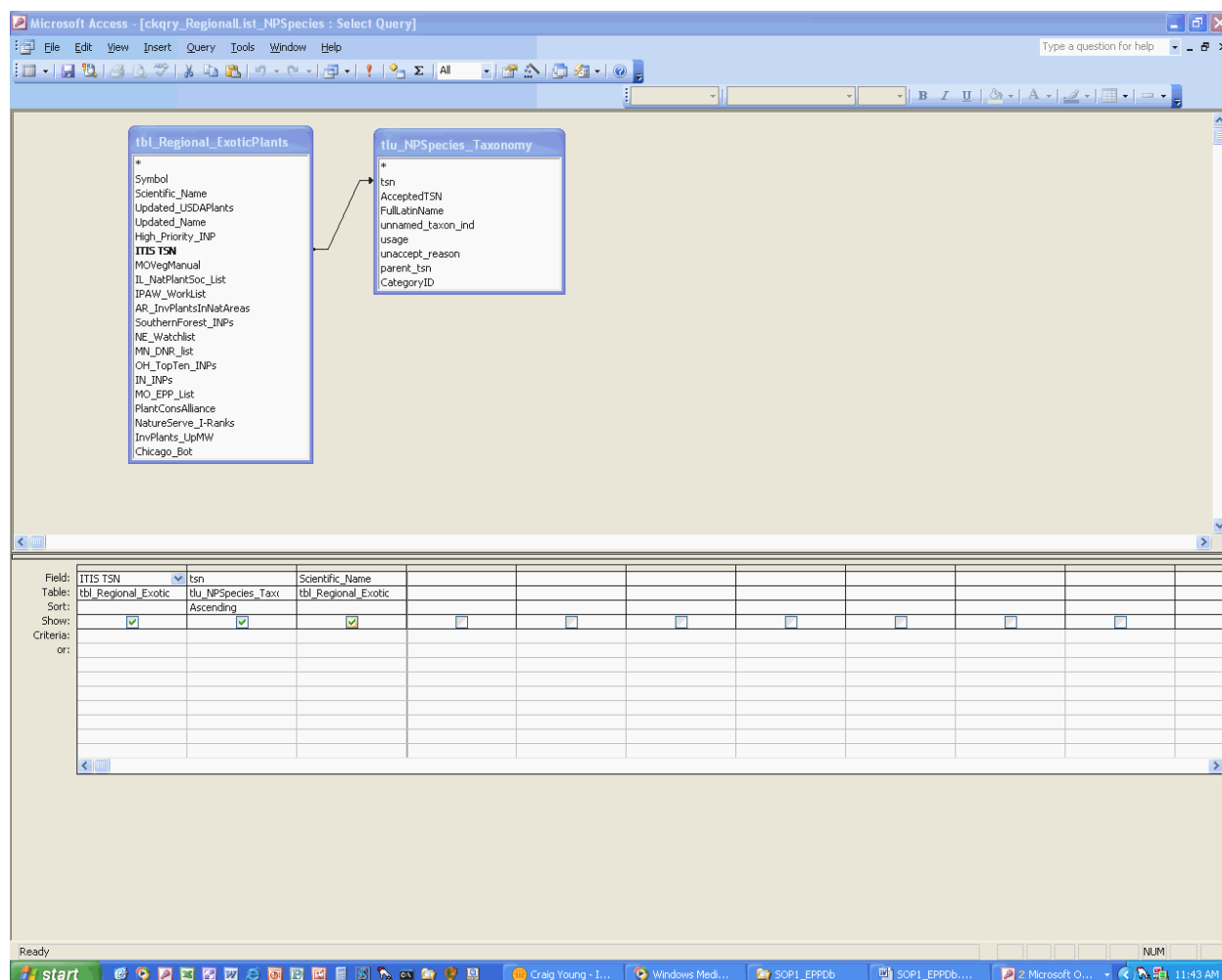


Figure 5.11. valqry_RegionalExotics_To_NPSpecies

V. Updating Exotic Plant Prioritization Database Tables

Table 1: tbl USDA Plants

The table is created using an advanced query in the USDA Plants database (http://plants.usda.gov/cgi_bin/topics.cgi?earl=advquery/adv_query.html) and should be updated annually. The query can be repeated as needed following the guidelines in section II. The query, valqry_RegionalExotics_To_USDAPlants, should be reviewed following any updates.

Table 2: tbl Regional ExoticPlants

The table should be updated annually to incorporate changes to plant lists and plant nomenclature. The query, valqry_RegionalExotics_To_USDAPlants, can be used to assure that nomenclature is current. If not, records may be updated as needed. As more tables are added as source information, new records may be added following procedures outlined in section II. Source information should be documented in the properties view of tbl_Regional_ExoticPlants

Table 3: tbl_NPSpecies

As new information is entered and edited in NPSpecies, tbl_NPSpecies in the PriorityDB should be updated annually. This is accomplished by using the Utilities: Download function in NPSpecies, which allows all of the species occurrences to be downloaded in Access format on a park-by-park basis as outlined in section II. The most recent download is assumed to provide the most accurate occurrence data.

Table 4: tbl_NPSpecies_Nativity

This table from NPSpecies is not expected to change, but this should be verified by looking at the latest desktop version of NPSpecies.

Table 5: tbl_NPSpecies_Taxonomy

This look-up table from NPSpecies should be updated annually following the methods outlined for tbl_NPSpecies.

Table 6: tbl_ParkBased_ExoticPlants

Data may be manually entered or removed as needed based on updates to NPSpecies, USDA Plants, the regional exotic plant list, new information, and shifting management priorities.

**Invasive Exotic Plant Monitoring Protocol
Heartland Network I&M Program**

Standard Operation Procedure 6: Data Management

Version 1.00 (7/1/2007)

Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

I. Overview of Data Management Process

Data management can be divided into: (a) the initial design phase that involves defining the data model, its entities, and their relationships; and (b) the procedures necessary to develop and maintain the database. Microsoft (MS) Access 2003 is the primary software used for maintaining invasive exotic plant (IEP) data. Environmental Systems Research Institute (ESRI) ArcInfo 9.x is used for managing spatial data associated with field sampling locations. Data products derived from this project will be available at the NPS I&M Data Store. QA/QC guidelines in this document are based on recommendations of Rowell and Williams (2005).

II. Data Model

The invasive exotic plant location geodatabase (LocationGDB) shown in Figure 6.1 manages the spatial and non-spatial data for the project. The spatial data, consisting of exotic plant search units, line transects, endpoints and midpoints of the line transects, grid cells, and reference frames, are housed in four feature datasets within the geodatabase. A separate feature dataset contains feature classes for each Universal Transverse Mercator (UTM) coordinate zone. The non-spatial data consists of eight tables within the geodatabase. Field data are found in tbl_FieldData. The tables, tbl_LocationID and tbl_SamplingPeriods, contain sampling location and time of data collection, respectively. The table tbl_Observers_hrs documents field and travel time for staff involved in a data collection for a particular sampling period. The table tbl_Regional_ExoticPlants is linked from the invasive exotic plant prioritization database (PriorityDB, see SOP 5). Three look-up tables provide ancillary information: tlu_Species, tlu_CoverClass, and tlu_StaffCooperators. The table tlu_Species is a central look-up table used to maintain consistency in taxonomy among network projects. The table tlu_CoverClass defines the endpoints and midpoints associated with the cover class scale. The table tlu_StaffCooperators provides information about the observers involved in monitoring. A diagram of LocationGDB tables and their relationships is shown in Figure 6.2.

III. Data Recording and Data Entry

Prior to data entry for an exotic plant monitoring event, the sampling event information must be directly entered in tbl_SamplingPeriod. Likewise tbl_Observers must be updated directly. Entry of field data in tbl_FieldData is controlled with a form (frm_IEPData) using drop-down menus (Figure 6.3).

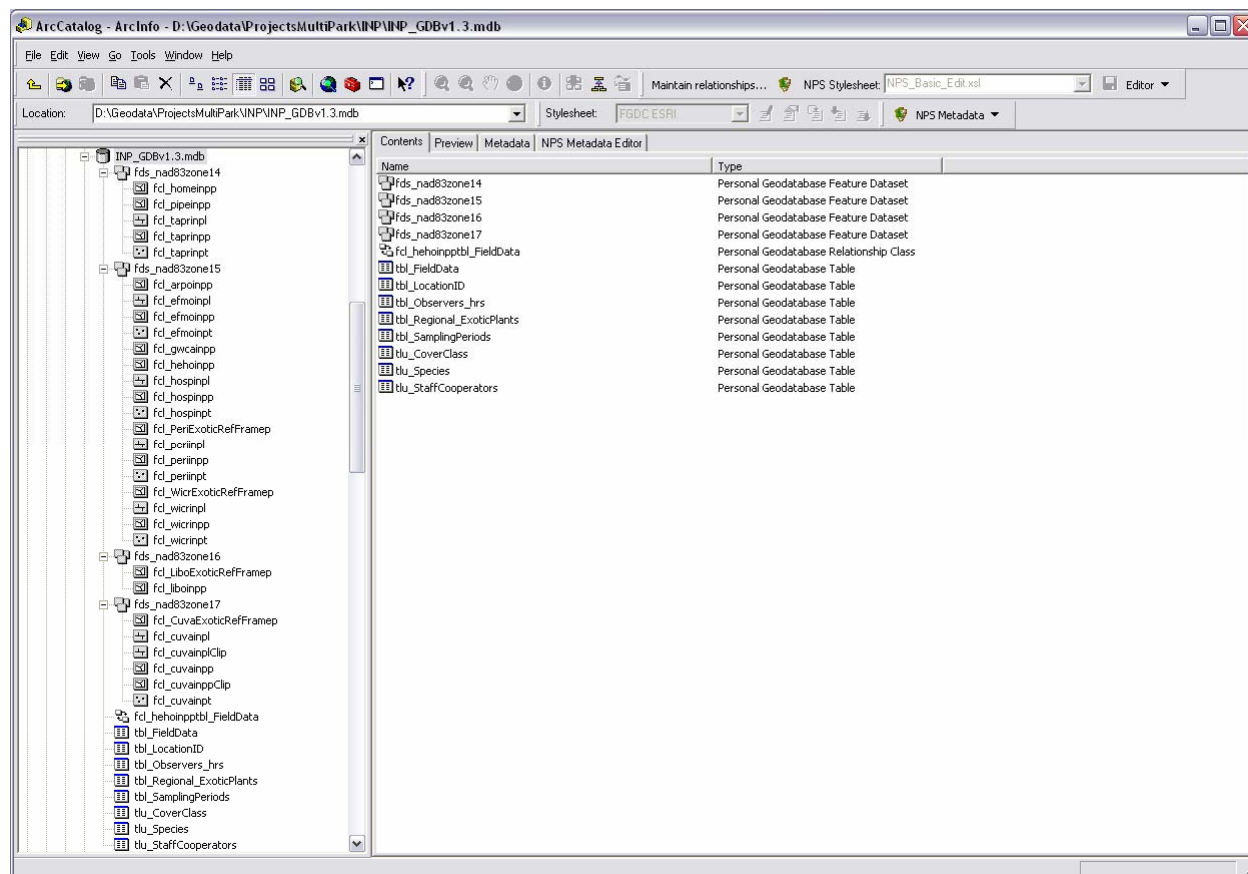


Figure 6.1. Data model for exotic plant monitoring information geodatabase (LocationGDB).

IV. Data Verification

Data verification requires a check of the accuracy of computerized records against the original data source, usually paper field records, in order to minimize transcription errors. To this end, staff that understand data collection procedures verify all records to their original source. Additionally, the project manager reviews ten percent of the records a second time and the results of that comparison are reported with the data. If errors are found during this second review, the entire data set is verified again. Once the electronic data are verified as accurately reflecting the original field data, paper data sheets are archived. The electronic version is used for all subsequent data activities.

V. Data Validation

Correctly transcribed data may still contain errors in accuracy. Validation procedures seek to identify generic errors (e.g. missing, mismatched, or duplicate records) as well as errors specific to particular projects. For example, a cover class for an IEP may be entered that is outside of the range of the available classes. In the case of LocationGDB, the controls associated with the data entry form automatically validate data because numerous inaccurate or illogical entries are prohibited. The project manager reviews the data to ensure that the plants recorded in the database were the same plants observed in the field. Any changes made to the data during the data validation phase should be made with marginal notes on the original field forms rather than by erasure. Once validation is complete, the data set is turned over to the data manager for archiving and storage. The data can then be used for all subsequent data activities.

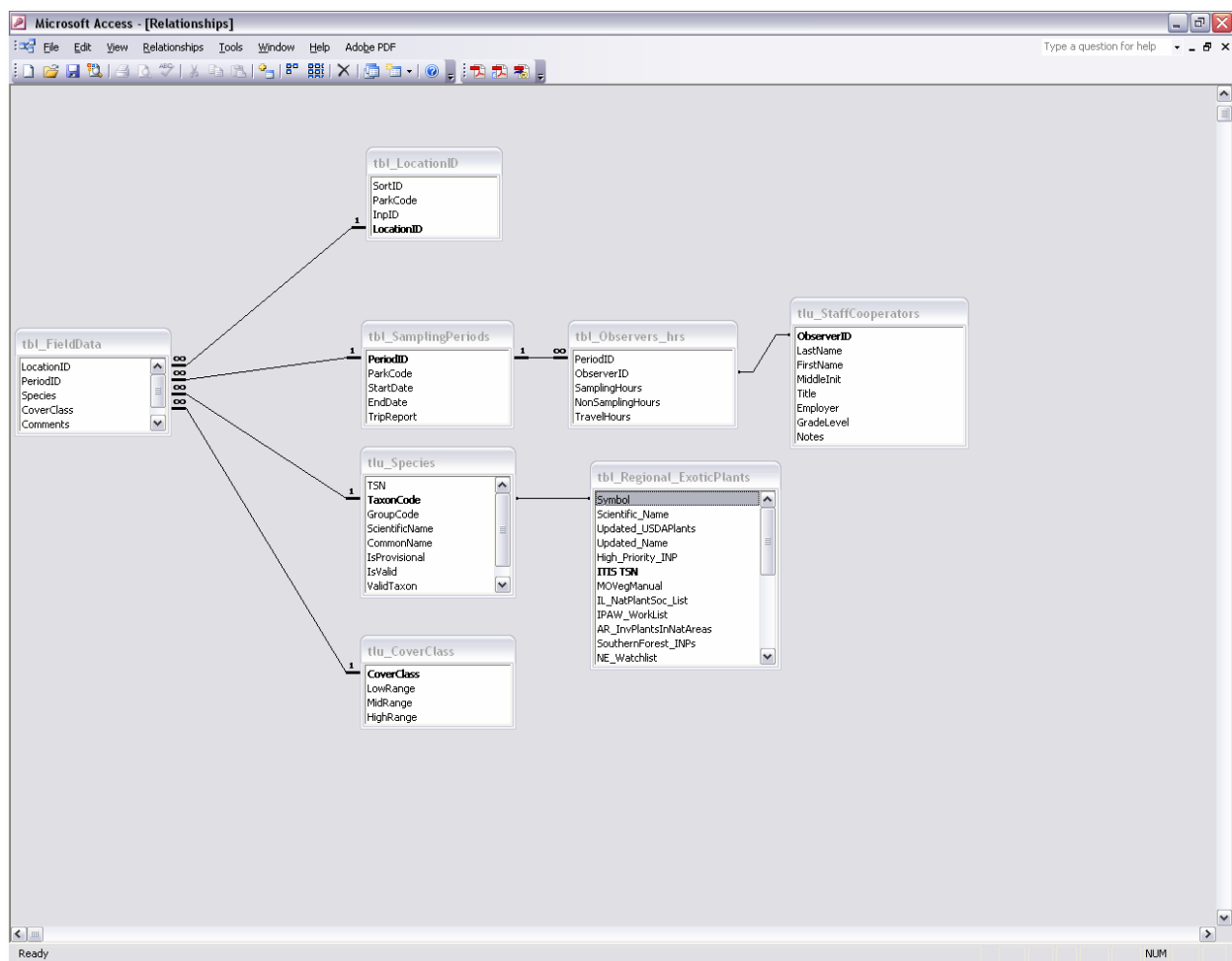


Figure 6.2. Relationships for exotic plant monitoring location geodatabase (Location GDB) tables.

VI. File Organization

The various databases, reports, and GIS layers used and generated by HTLN create a large number of files and folders to manage. The file structure depicted in Figure 6.4 is used for the exotic plant monitoring project. Files pertaining to the project are managed in their own folder: “analysis” for data analysis, “data” for copies of archived data as well as data sheets, “documents” for written materials related to the project, and “spatial info” for spatial data. LocationGDB is stored in the “geodatabases” folder while the PriorityDB database is managed in the “databases” folder. The folders contain prior versions of the database in a subfolder called “dev”.

Data management files consist primarily of two databases and one set of files.

- a) PriorityDB – Generates early detection, park-established, and park-based exotic plant watch lists. See SOP 5.
- b) LocationGDB – Manages location and attribute data for the exotic plant search units or line transects.
- c) Navigation files – Includes .imp, .wpt, and .tif files used for navigation through search units and along line transects. See SOPs 3 and 4.



Figure 6.3. Data entry form, frm_ExoticPlantData, for invasive exotic plant data.

VII. Version Control

Prior to any major changes of a data set, a copy is stored with the appropriate version number. This allows for the tracking of changes over time. With proper controls and communication, versioning ensures that only the most current version is used in any analysis. Versioning of archived data sets is handled by adding a floating-point number to the file name with the first version being numbered 1.00. Each major version is assigned a sequentially higher whole

number. Each minor version is assigned a sequentially higher .1 number. Major version changes include migrations across Access versions and complete rebuilds of front-ends and analysis tools. Minor version changes include bug fixes in front-end and analysis tools. Frequent users of the data are notified of the updates and provided with a copy of the most recent archived version.

Data sets often change through additions, corrections, and improvements made following data verification. Three rules should be observed in this process:

- a) Only make changes that improve or update the data while maintaining data integrity.
- b) Once archived, document any changes made to the data set.
- c) Be prepared to recover from mistakes made during editing.

Any editing of archived data is accomplished jointly by the project manager and data manager. Every change must be documented in the edit log and accompanied by an explanation that includes pre- and post-edit data descriptions. Original field forms are not altered. Field forms can be reconciled to the database through the use of the edit log.

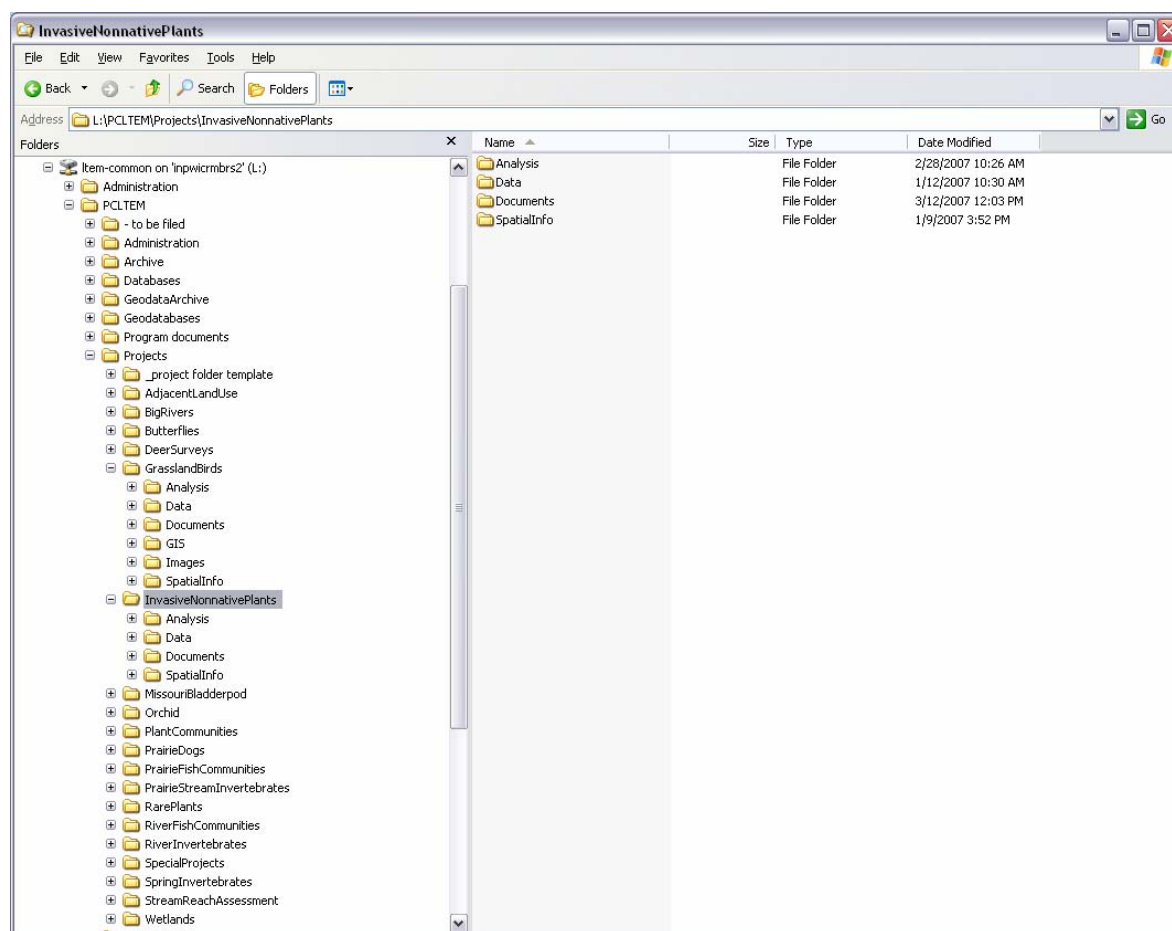


Figure 5.4. Invasive exotic plant monitoring project structure.

VIII. Backups

Data archiving is the most important data management activity. Servers that go down may not come back. The data manager needs to be able to restore data to alternate servers or workstations. In this sense, a reliable tape backup device is more critical than the server itself. Complete backups of all databases (i.e., no incremental backups) run on Monday, Wednesday, and Friday. Monday tapes are held for a month. Archive tapes are made quarterly and stored for 18 months. Back-up logs are reviewed on every job and file restores are run once per month just to be sure the system is working. A copy of all project databases is also stored at the NPS Inventory and Monitoring Data Store.

IX. Data Availability

Currently, data are available for research and management applications for those database versions where all QA/QC has been completed and the data have been archived. Data can be transferred using ftp or e-mail depending on file size. Monitoring data may also be available for download directly from the NPS I&M Data Store. Metadata for the exotic plant database are developed using ESRI ArcCatalog 9.x and the NPS Metadata Tools and Editor extension. Metadata will be available at the NPS I&M application server:
<http://science.nature.nps.gov/im/apps.htm>. Additionally, data requests can be directed to:

Heartland I&M Network
Attn. Data Manager
Wilson's Creek National Battlefield
6424 W. Farm Road 182
Republic, MO 65738-9514
417-732-6438
Gareth_Rowell@nps.gov

**Invasive Exotic Plant Monitoring Protocol
Heartland Network I&M Program**

Standard Operation Procedure 7: Data Analysis

Version 1.00 (7/1/2007)

Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

I. Mapping

Maps will be designed to show the distribution and abundance of invasive exotic plants (IEPs) on monitored parks. Maps are constructed using LocationGDB. First, tables are created in LocationGDB for each IEP species in each park for the monitoring year of interest. The LocationID field is then used to link cover values of an IEP species to park search units or line transects. Search units and line transects are maintained as feature classes in LocationGDB. A separate map will be constructed for each IEP at each park (for example, see Figure 7.1). Maps are intended to assist resource managers in designing IEP control strategies. New IEP invasions, IEP concentrations, and IEP-free areas will be highlighted on these maps.

II. Frequency

For the purposes of this protocol, frequency is defined as the proportion of search units or line transects in which an IEP occurs. Frequency will be calculated in the following manner:

$$\text{Equation 7.1 Frequency of an IEP species} = \frac{\sum \text{units occupied by species}}{\sum \text{units sampled}}$$

III. Cover

To calculate the minimum cover for each IEP species on each park, the lower endpoints of the cover class values assigned for that species to each search unit were summed and divided by the fraction of park observed assuming that a 12-m belt was surveyed. Maximum cover was calculated using the upper endpoints of the cover values in each search unit and assumed that a 3-m belt was surveyed. Transect lengths were calculated for each park using the mean sample unit size and assuming square search units. High and low estimates were then summed across species, respectively, to estimate the range of total HPIP cover for each park. Non-overlapping cover ranges are considered significantly different. See equations 7.2-7.4.

Based on a study of the six smaller parks (reference frame ≤ 350 acres/ ha), under the most extreme scenario in which all actual cover values lie at the low end of the assigned cover class, four doubling periods would be required to detect a change in total HPIP cover at each park. (Doubling periods as a percentage change: 1 = 200 %, 2 = 400 %, 3 = 800 %, 4 = 1600 %, 5 = 3200 %, and 6 = 6400 %). Examining the 135 IEP occurrences on the six parks, change would be detected for 4.4 %, 33.6 %, 24.8 %, and 37.2 % of IEPs following 3, 4, 5, and 6 doubling periods, respectively.

$$\text{Equation 7.2 Fraction of park observed} = \frac{\text{transect length} * \text{number of transects} * \text{belt width}}{\text{reference frame area}}$$

$$\text{Equation 7.3 Reference frame-wide IEP cover, low estimate} = \frac{\sum \text{low end of cover value range for species}}{\text{fraction of area searched assuming 12-m belt}}$$

$$\text{Equation 7.4 Reference frame-wide IEP cover, high estimate} = \frac{\sum \text{high end of cover value range for species}}{\text{fraction of area searched assuming 3-m belt}}$$

IV. Search Unit/Transect-Based Metrics

The calculation of reference frame-wide IEP cover does not require the use of permanent plots. The semi-permanent plots used in this design (see SOP 3), however, allow changes in individual search units or line transects to be studied. Three calculations compare changes in individual cells: 1) change in density class for each cell between years (Equation 7.5), 2) overlap in cell occupancy for all pair-wise year combinations (Equation 7.6), and 3) persistence over all sampling periods (Equation 7.7). Overlap in cell occupancy is calculated as the percentage of cells occupied in common during two years relative to the number of plots occupied during the year with the least number of occupied plots.

$$\text{Equation 7.5 Change in density class in individual cells} = (\text{density class in search unit/ transect during time 2} - \text{density class in search unit/transect during time 1})$$

$$\text{Equation 7.6 Overlap in search unit/transect occupancy} = \frac{\text{number of cells occupied in Time 1 and time 2}}{\text{the lower of the number of cells occupied in Time 1 or Time 2}}$$

$$\text{Equation 7.7 Persistence} = \frac{\text{number of sampling periods in which a search unit or transect was occupied}}{\text{total number of sampling periods}}$$

V. Habitat Relationships

Habitat data available in the network GIS will be evaluated as predictors of plant abundance and presence to the extent possible. While such information is potentially helpful in identifying invasion pathways, this objective is a peripheral analytical objective.

VI. Detection Probability and Measurement Error

IEP detection probabilities depend on the amount of preferred habitat searched, taxonomic and search skills of the observer, physical characteristics of the plant, search effort in terms of time and area, and nature of the surrounding vegetation and terrain, which determines the difficulty of navigation and the degree of difficulty in observing the plant. With increasing abundance of an exotic plant, frequency measures are less sensitive to detection probabilities because accurate measurement only requires one plant to be observed on the line transect. However, because factors affecting detection may change, some detection error is expected. Cover estimation is strongly dependent on detection as well as the skill of the observer in integrating cover over large areas. Cover estimates are expected to vary to some degree across monitoring periods based on these differences. Consequently, change in frequency and cover must be considered in terms of magnitude and relative to cover measurements from previous years.

The following should be kept in mind when interpreting the data:

1. If an IEP is at least moderately abundant, the plant will likely be detected again during subsequent surveys despite these sources of error.
2. If an IEP is uncommon, the plant may be missed in some years and found in other years. Such turnover would be expected only for sampling units in which a plant was assigned a low cover value. Turnover rates should be roughly equal each year. A dramatic change in these rates from year to year would be interpreted as stronger evidence of a true change.
3. Changes of greater magnitude than one density class category between years are more likely to represent true changes. Such changes should be brought to the attention of park natural resource managers.
4. For parks that choose to record IEP management actions using exotic plant search polygons, we will determine if changes in plant occurrence or cover are associated with management actions.

VII. Long-term Trend Analyses

Invasive plant metrics should be graphed over time. A control chart approach could be used to set thresholds related to management actions. For example, once an invasive species reaches a certain level of abundance, it may no longer be cost-effective to attempt eradication or control. The use of control charts for ecological monitoring is beyond the scope of this SOP, but is described in several texts (Beauregard et al. 1992, McBean and Rovers 1998, Gyrna 2001, Manly 2001, Montgomery 2001).

Regression analyses could be used to estimate rates of change or the trajectory of change (i.e., linear or nonlinear) in invasive plant metrics. Because most parks will only be sampled every five years, and sample size in such analyses is equal to number of sampling occasions, the relationship between sample size and statistical power must be kept in mind.

A repeated measures ANOVA could be employed. This approach would be particularly informative in a scenario in which control of invasive plants was attempted in some management areas of a park and not in others. If conducted as a properly controlled, randomized experiment, a repeated measures ANOVA would be a very powerful means of evaluating the effects of such treatments.

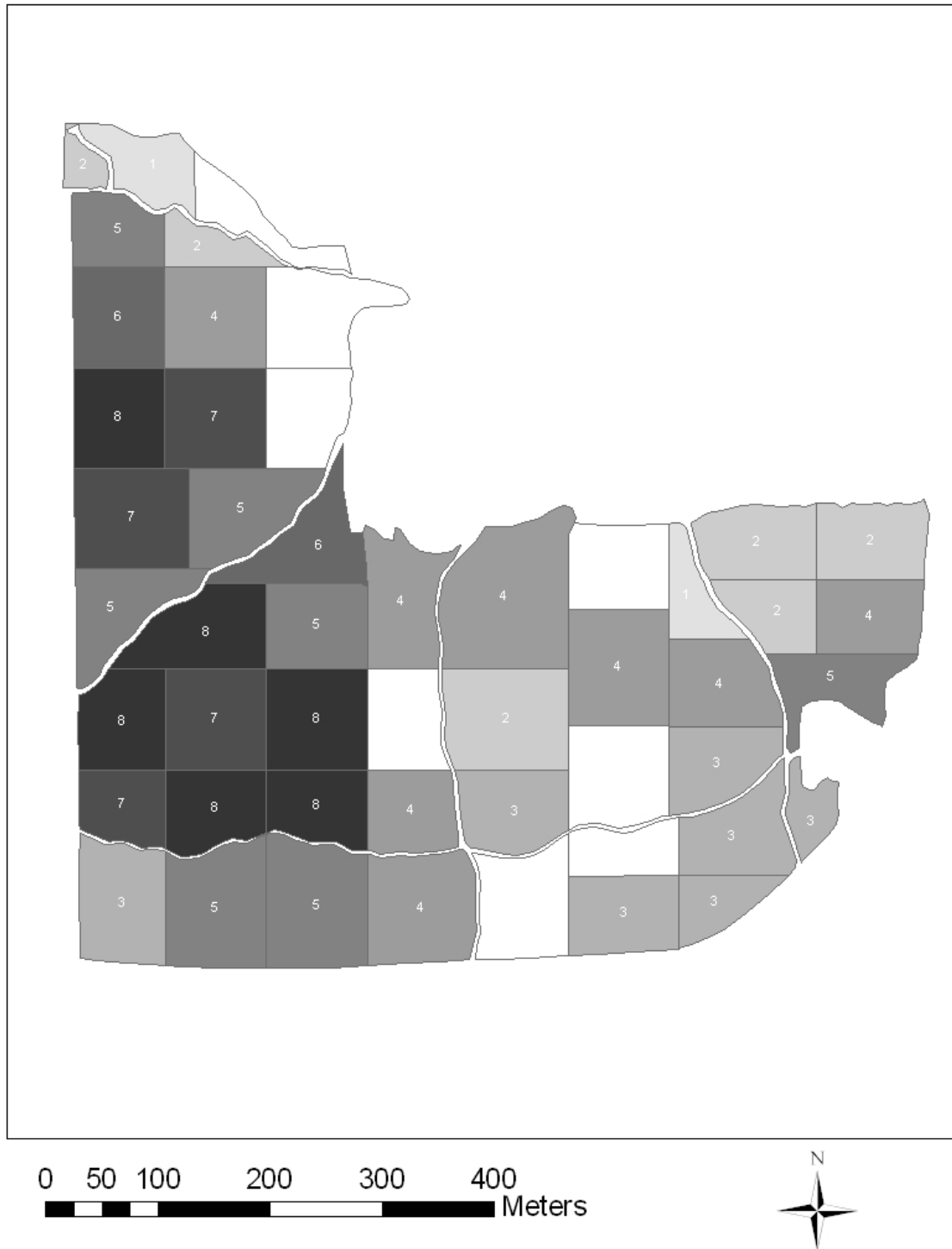


Figure 7.1. Map of sweet clover (*Melilotus* spp.) distribution at Herbert Hoover National Historic Site. Exotic plant search units are labeled with cover class values: 0=0, 1=0.1-0.9 m², 2=1-9.9 m², 3=10-49.9 m², 4= 50-99.9 m², 5=100-499.9 m², 6= 499.9-999.9 m², and 7=1,000-4,999.9 m².

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**Invasive Exotic Plant Monitoring Protocol
Heartland Network I&M Program**

Standard Operation Procedure 8: Reporting

Version 1.00 (7/1/2007)

Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

I. Report Format

Template

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

Style

Standards for scientific writing as recommended in the CBE Style Manual (CBE Style Manual Committee 1994) should be followed. Reports should be direct and concise. Authors of reports should also refer to Mack (1986), Goldwasser (1999), Strunk and White (2000), and Day and Gatsel (2006).

II. Types of Reports and Review Process

Table 7.1 summarizes the types of reports produced and the review process. Adapted from Debacker *et al.* 2005.

Type of Report	Purpose of Report	Primary Audience	Review Process	Frequency
Annual Status Reports for Specific Protocols	Summarize monitoring data collected during the year and provide an update on the status of selected natural resources. Document related data management activities and data summaries.	Park resource managers and external scientists	Internal peer review by HTLN staff	Annually
Executive Summary of Annual Reports for Specific Protocols	Same as Annual Status Reports but summarized to highlight key points for non-technical audiences.	Superintendents, interpreters, and the general public	Internal peer review by HTLN staff	Simultaneous with Annual Status Reports
Comprehensive Trends and Analysis and Synthesis Reports	Describe and interpret trends in individual vital signs. Describe and interpret relationships among observed trends and park management, known stressors, climate, <i>etc.</i> Highlight resources of concern that may require management action.	Park resource managers and external scientists	Internal peer review by HTLN staff	Every 5-7 years
Executive Summary of Comprehensive Trends and Analysis and Synthesis Reports	Same as Comprehensive Trends and Analysis and Synthesis Reports, but summarized to highlight findings and recommendations for non-technical audiences.	Superintendents, interpreters, and the general public	Internal peer review by HTLN staff	Simultaneous with Comprehensive Trends Analysis and Synthesis Reports

III. Report Distribution

Following review, annual reports will be distributed by May 1 of the year following data collection. Reports can also be distributed to partners involved in conservation of the monitored resource. This determination is made by the park, the network, or the regional office. All data collected is public property and subject to requests under the Freedom of Information Act (FOIA). However, sensitive data, such as the location of rare species, must be withheld in some cases. Reports containing non-sensitive data will be made publicly available and disseminated through the network website and the biodiversity data store (<http://www.nature.nps.gov/biology/biologicalinventories/biodiversitydatastore.cfm>).

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**Invasive Exotic Plant Monitoring Protocol
Heartland Network I&M Program**

Standard Operation Procedure 9: Revising the Protocol

Version 1.00 (7/1/2007)

Revision History Log:

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

I. Procedures

1. In the event that the invasive exotic plant (IEP) monitoring protocol requires editing, all edits must be reviewed for technical merit. Minor changes to the protocol will only require in-house review by network staff. Subject matter experts must review major protocol changes.
2. Protocol edits and versioning are tracked in the revision history log attached to each narrative and SOP. Major changes result in an update by whole numbers (i.e. version 1.00, version 2.00, etc.) and minor changes by hundredths (e.g., version 1.01, version 1.02, etc). Record the previous version number, date of revision, author of the revision, describe the change, provide a rationale for the change, and assign a new version number.
3. Inform the data manager about changes to the protocol narrative or SOPs, so the new version number can be incorporated in the project database metadata. The data manager may need to edit the database if the changes affect database structure.
4. Post new protocol versions on the network website and forward copies to all individuals with a previous version of the affected protocol narrative or SOP.

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The NPS has organized its parks with significant natural resources into 32 networks linked by geography and shared natural resource characteristics. HTLN is composed of 15 National Park Service (NPS) units in eight Midwestern states. These parks contain a wide variety of natural and cultural resources including sites focused on commemorating civil war battlefields, Native American heritage, westward expansion, and our U.S. Presidents. The Network is charged with creating inventories of its species and natural features as well as monitoring trends and issues in order to make sound management decisions. Critical inventories help park managers understand the natural resources in their care while monitoring programs help them understand meaningful change in natural systems and to respond accordingly. The Heartland Network helps to link natural and cultural resources by protecting the habitat of our history.

The I&M program bridges the gap between science and management with a third of its efforts aimed at making information accessible. Each network of parks, such as Heartland, has its own multi-disciplinary team of scientists, support personnel, and seasonal field technicians whose system of online databases and reports make information and research results available to all. Greater efficiency is achieved through shared staff and funding as these core groups of professionals augment work done by individual park staff. Through this type of integration and partnership, network parks are able to accomplish more than a single park could on its own.

The mission of the Heartland Network is to collaboratively develop and conduct scientifically credible inventories and long-term monitoring of park “vital signs” and to distribute this information for use by park staff, partners, and the public, thus enhancing understanding which leads to sound decision making in the preservation of natural resources and cultural history held in trust by the National Park Service.

www.nature.nps.gov/im/units/htln/



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

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**National Park Service
U.S. Department of the Interior**



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