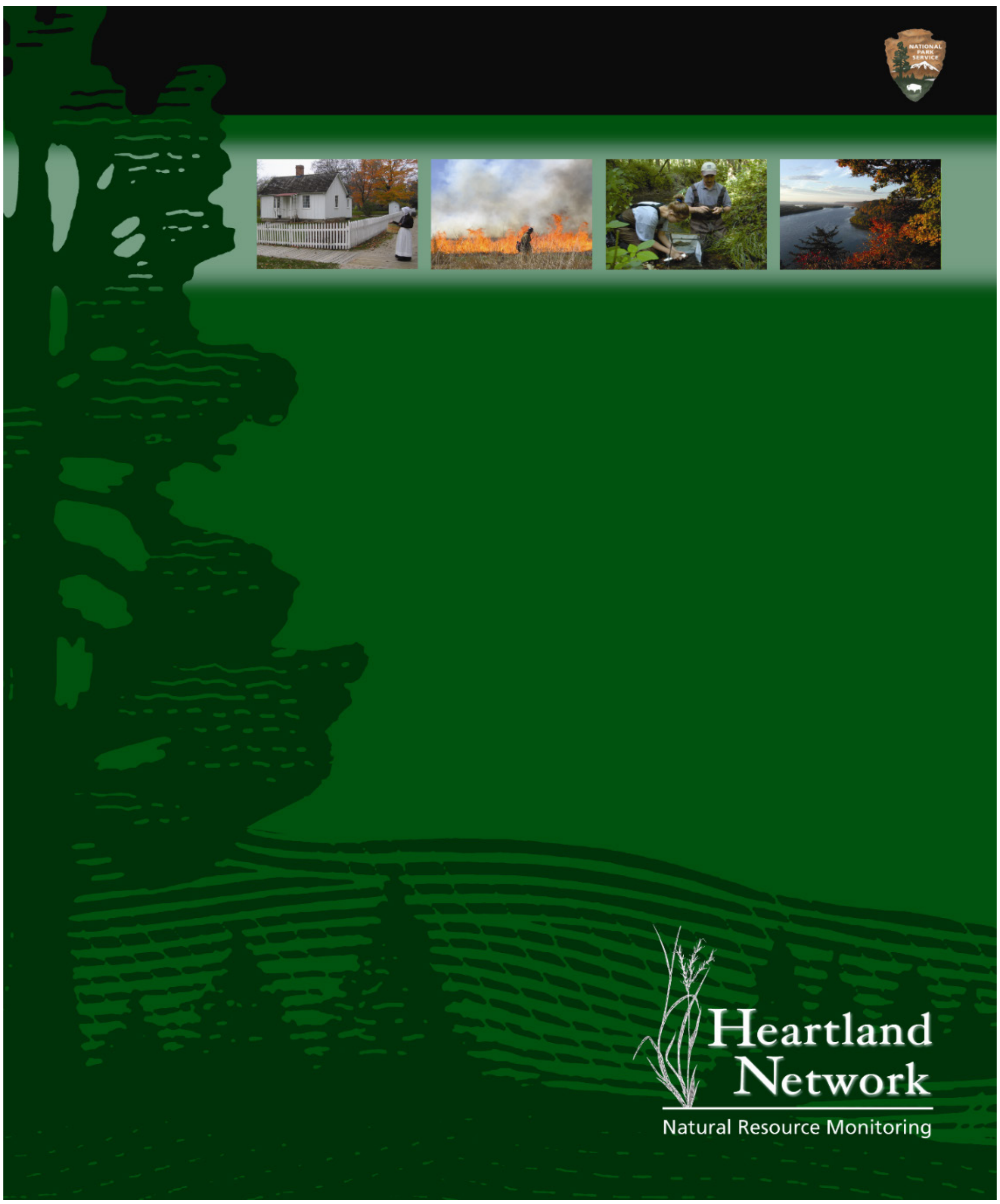
National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Protocol for Monitoring Fish Communities in Small Streams in the Heartland Inventory and Monitoring Network

Version 2.0

Natural Resource Report NPS/HTLN/NRR—2021/2235



ON THE COVER
IHerbert Hoover birthplace cottage at Herbert Hoover NHS, prescribed fire at Tallgrass Prairie NPres, aquatic invertebrate monitoring at George Washington Carver NM, and the Mississippi River at Effigy Mounds, NM
Photography by NPS

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March 2021

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

This report is available from the Heartland Network Inventory and Monitoring website and the Natural Resource Publications Management website. If you have difficulty accessing information in this publication, particularly if using assistive technology, please email irma@nps.gov.

Please cite this publication as:

Dodd, H. R., D. G. Peitz, G. A. Rowell, J. A. Hinsey, D. E. Bowles, L. W. Morrison, M. D. DeBacker, J. L. Haack-Gaynor, and J. M. Williams. 2021. Protocol for monitoring fish communities in small streams in the Heartland Inventory and Monitoring Network: Version 2.0. Natural Resource Report NPS/HTLN/NRR—2021/2235. National Park Service, Fort Collins, Colorado. https://doi.org/10.36967/nrr-2284726.

NPS 920/175110, March 2021

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Protocol Revision Log

Protocol revision and version information.

Prev. Version #	Revision Date	Author (s)	Changes made	Reason for Change	New Version #
1.00	March 2016–March 2020	Hope R. Dodd, Janice A. Hinsey, David E. Bowles, Lloyd W. Morrison, Gareth A. Rowell, Michael D. DeBacker, David Peitz,, Jennifer L. Haack-Gaynor, Jeff M. Williams	• Modified revisit design for PIPE and TAPR. • Added IMD guidance for Data Management, Reporting and Protocol Revision. • Revised Data Management to reflect changes in database structure. • Added new analysis methods. • Specific details on changes to protocol are under Protocol Narrative Revision History section, Table 9.	Recommendations described in Fancy (2008), DeBacker et al. (2012), Frakes et al. (2015), DeVivo (2016), NPS (2016), Frakes and Kingston (2017), Mitchell et al. (2018), and Gallo (2018) memo	2.0

Standard Operating Procedures:

The SOPs for this protocol: Protocol for Monitoring Fish Communities in Small Streams in the Heartland Inventory and Monitoring Network: Version 2.0.

SOP 1: Preparation for Field Sampling, Version 1.1

SOP 2: Training, Version 1.1

SOP 3: Documenting CORE 5 Water Quality Variables, Version 1.1

SOP 4: Fish Community Sampling, Version 1.1

SOP 5: Physical Habitat Measurements, Version 1.1

SOP 6: Measuring Stream Discharge, Version 1.1

SOP 7: Equipment Storage and Maintenance, Version 1.1

SOP 8: Data Management, Version 2.0

SOP 9: Data Analysis, Version 2.0

SOP 10: Data Reporting, Version 2.0

SOP 11: Revising the Standard Operation Procedures, Version 2.0

Executive Summary

Fish communities are an important component of aquatic systems and are good bioindicators of ecosystem health. Land use changes in the Midwest have caused sedimentation, erosion, and nutrient loading that degrades and fragments habitat and impairs water quality. Because most small wadeable streams in the Heartland Inventory and Monitoring Network (HTLN) have a relatively small area of their watersheds located within park boundaries, these streams are at risk of degradation due to adjacent land use practices and other anthropogenic disturbances. Shifts in the physical and chemical properties of aquatic systems have a dramatic effect on the biotic community. The federally endangered Topeka shiner (*Notropis topeka*) and other native fishes have declined in population size due to habitat degradation and fragmentation in Midwest streams. By protecting portions of streams on publicly owned lands, national parks may offer refuges for threatened or endangered species and species of conservation concern, as well as other native species.

This protocol describes the background, history, justification, methodology, data analysis and data management for long-term fish community monitoring of wadeable streams within nine HTLN parks: Effigy Mounds National Monument (EFMO), George Washington Carver National Monument (GWCA), Herbert Hoover National Historic Site (HEHO), Homestead National Monument of America (HOME), Hot Springs National Park (HOSP), Pea Ridge National Military Park (PERI), Pipestone National Monument (PIPE), Tallgrass Prairie National Preserve (TAPR), and Wilson's Creek National Battlefield (WICR). The objectives of this protocol are to determine the status and long-term trends in fish richness, diversity, abundance, and community composition in small wadeable streams within these nine parks and correlate the long-term community data to overall water quality and habitat condition (DeBacker et al. 2005).

Acknowledgments

We would like to thank the park staff at TAPR and PIPE for the review of proposed changes to the revisit design of version 1.0 of this protocol (Dodd et al. 2008). We would also like to acknowledge Tyler Cribbs and the many HTLN staff, park staff, interns, and volunteers who assisted with the collection of data used to reevaluate the protocol. Thanks also to the peer reviewers of this protocol (version 2.0).

Heartland Inventory and Monitoring Network

The National Park Service has organized its parks with significant natural resources into 32 networks linked by geography and shared natural resource characteristics. The Heartland Inventory and Monitoring (I&M) Network (Heartland Network) is composed of 15 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 the Heartland Network, 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.

https://www.nps.gov/im/htln/index.htm

Heartland Network

Natural Resource Monitoring

Background and Objective

Issues Being Addressed and Rationale for Fish Community Monitoring

Many lotic systems in the United States are in a degraded condition, largely as a result of watershed level land use changes and corresponding water pollution problems (USEPA 1990). During the last century, large portions of grassland landscapes have been converted to cropland or livestock pasture (Knopf and Samson 1997), increasing sedimentation, nutrient loading, and other chemical pollution in streams. Nonpoint source pollution from agricultural practices is regarded as the largest long-term threat to streams in the Midwest (USEPA 1995).

Other activities such as logging (and associated road construction) and urban development also negatively impact water quality by increasing surface water runoff and introducing chemical pollutants and soil from upland areas. These land use changes result in water quality alterations and modifications to the natural hydrology and physical habitat of streams, and they exacerbate the effects of flood events. Impacts to stream integrity and habitat include increases in spate intensity, shifts in channel geomorphology, and increases in bed and bank erosion, altered light penetration, and water temperature regimes.

Although protecting riparian corridors may help mitigate some of these problems (Peterjohn and Correll 1984; Osborne and Kovacic 1993; Stauffer et al. 2000), changes in land use practices within the watershed can overwhelm localized protection of stream corridors (Richards et al. 1996; Roth et al. 1996; Wang et al. 1997; Weigel et al. 2000). Because processes occurring in the entire watershed and the riparian areas are not independent of each other (Doppelt et al. 1993), improving or maintaining stream integrity through partial protection of the watershed or stream corridor can be difficult and, in certain situations, impractical.

The National Park Service (NPS) has mandated that park managers establish baseline data or vital signs and long-term monitoring programs for the natural resources found within their parks. Monitoring information is intended to help address current resource problems while allowing managers to anticipate and plan for future resource issues. Maintaining the integrity of stream ecosystems so that they remain comparable to least disturbed streams of the region clearly warrants monitoring (Karr and Dudley 1981; Angermeier and Karr 1994). Because most small wadeable streams in the Heartland Inventory and Monitoring Network (HTLN) have a relatively small area of their watersheds located within park boundaries, these streams are at risk of degradation due to adjacent land use practices and other anthropogenic disturbances.

To monitor the status of aquatic resources, one or more biotic components (e.g., aquatic vegetation, invertebrates, fish) of a stream may serve to measure its ecological integrity. The US Environmental Protection Agency (USEPA) uses a Rapid Bioassessment Protocol (RBP) to allow for quick and broad monitoring of periphyton, macroinvertebrates, and fish in streams (Barbour et al. 1999), and they developed an Environmental Monitoring and Assessment Program (EMAP; Lazorchak et al. 1998) for more rigorous data collection of these same biotic components. The US Geological Survey (USGS) utilizes an in-depth data collection of algae, macroinvertebrates, and fish in their National Water Quality Assessment Programs (NAWQA; Moulton et al. 2002).

Fish communities of lotic systems are an important component of their aquatic ecosystems. Many fish species are considered intolerant of habitat alterations (Karr 1981; Robison and Buchanan 1988; Pflieger 1997; Barbour et al. 1999) and monitoring their assemblages can serve as a useful tool to assess changes in water and habitat quality (Hoefs and Boyle 1990; Peitz 2005; Petersen and Justus 2005a, b, c, d). Accordingly, trends in the composition and abundance of fish populations historically have been used to assess the biological integrity of streams (Barbour et al. 1999; Moulton et al. 2002). Moreover, the intrinsic value of fish to the public as environmental indicators and as a recreational opportunity makes the status of fish diversity a valuable interpretive topic for park visitors and an informative tool for supporting management decisions.

Many native fish populations have been impacted adversely throughout their ranges by a number of factors associated with land use changes and the loss of natural habitat. Among these impacts are habitat loss due to stream degradation and modification such as channel dewatering, impoundments, channelization and fragmentation, in-stream gravel mining, and siltation. Biological impacts stemming from the introduction (both intentional and unintentional) of non-native fishes also have influenced the decline of native species (Kolar and Lodge 2002; Winston 2002; Irons et al. 2007). As a result of habitat loss and decline of water quality conditions in Midwestern streams, the Topeka shiner (*Notropis topeka*), a native prairie stream fish, has been listed as federally endangered under the Endangered Species Act of 1973. Currently, the Topeka shiner inhabits less than 10% of its historical range (Tabor 1998).

In addition to this federally protected species, several other stream fishes are impaired due to habitat loss and fragmentation in the Midwest, making it necessary for state agencies to protect these native species within their jurisdictions. Although anthropogenic disturbances at the watershed scale can dramatically alter a lotic system, protecting portions of small streams on publicly owned lands may offer refuges for threatened or endangered species and species of conservation concern, as well as other native species. NPS lands may provide some of the least impacted stream habitat remaining in the Midwest. As such, waterways on some NPS lands may contain habitat critical for sustaining populations of native fishes (Federal Register 2002).

Because changes or shifts in stream habitat complexity and water quality often determine biotic communities, including fish (Lazorchak et al. 1998), monitoring trends in fish community composition along with associated habitat conditions serves as a strong basis for measuring stream integrity. Assessment of chemical/physical characteristics in lotic systems is a common practice used to monitor aquatic conditions and determine potential areas of degradation or resource problems. Water quality assessment gives investigators immediate results but requires that sampling occur during or soon after a disturbance. Monitoring of biological resources complements water quality assessments because it can be used to assess longer term effects of disturbances on the aquatic system. A comprehensive monitoring program should include biotic indicators that respond or are linked to the physical and chemical conditions within the system. Information obtained from monitoring trends in fish communities, together with chemical and physical data, provides an integrated and robust assessment of stream integrity. Therefore, monitoring the current status and population trends of fish communities and their habitats is an important tool for preserving and conserving aquatic resources in national parks.

The framework for monitoring small streams located in HTLN parks is directed towards maintaining their ecological integrity, which will be assessed through periodic monitoring of fish communities, physical habitat, and water quality. This protocol has been designed to incorporate the spatial relationship of biotic indicators with chemical constituents and physical habitat and primarily draws on sampling methodology described in the USGS NAWQA protocol.

History of Monitoring Fish Communities in Small Streams within HTLN

In 2001–2003, the Prairie Cluster Prototype Long-term Ecological Monitoring Program began developing a protocol and initiated fish sampling at Pipestone National Monument (PIPE) and Tallgrass Prairie National Preserve (TAPR) to assess the integrity of prairie streams within their boundaries. Because the NPS was interested in locating and monitoring populations of the federally endangered Topeka shiner, the primary emphasis of this initial work was determining the status of this species, with secondary objectives of describing baseline fish communities and refining sampling techniques for prairie streams. A monitoring protocol for fish communities in prairie streams was developed for these two parks (called “prairie fish protocol” hereafter; see Peitz and Rowell 2004) and subsequent sampling was completed in 2004 and 2005. Fish communities and stream habitat were sampled at Homestead National Monument (HOME) in 2003 and 2004 (Peitz 2005) using methods described in the prairie fish protocol (Peitz and Rowell 2004). The primary purpose of this survey was to locate Topeka shiners and available habitat for this species within the park. In 2006, monitoring was continued at HOME using revised methods described in this protocol.

Aquatic monitoring in the smaller streams of parks within HTLN historically has been limited to a handful of prairie parks and focused primarily on the aquatic invertebrate community or water quality. Other than the long-term monitoring of Topeka shiner populations at PIPE and TAPR (Peitz and Rowell 2004), fish communities in smaller parks of HTLN have been surveyed only sporadically prior to the development of this protocol and primarily for the purpose of developing faunal inventories: George Washington Carver National Monument (GWCA; Petersen and Justus 2005c), Hot Springs National Park (HOSP; Petersen and Justus 2005a), Pea Ridge National Military Park (PERI; Petersen and Justus 2005d), and Wilson's Creek National Battlefield (WICR; Donegon 1984; Foster 1988; Hoeffs and Boyle 1990; Petersen and Justus 2005b).

Pilot fish monitoring was initiated at GWCA and WICR in 2006 to provide a more complete picture of the aquatic resources (in addition to already established aquatic invertebrate monitoring; see Boyle et al. 1990, Harris et al. 1991, Peterson et al. 1999, and Bowles et al. 2008b) within these wadeable streams. Several other network parks have notable aquatic resources, although long-term fish monitoring was not conducted in those parks prior to 2006. These parks include Herbert Hoover National Historic Site (HEHO), Effigy Mounds National Monument (EFMO), HOSP, and PERI. In 2007, fish monitoring was initiated in parks with small streams (i.e. wadeable) using methods described in "Protocol for Monitoring Fish Communities in Small Streams in the Heartland Inventory and Monitoring Network" (Version 1.0, Dodd et al. 2008), hereafter called "stream fish protocol."

In addition, aquatic invertebrate monitoring was also initiated in these same parks and sites were co-located with fish monitoring (Bowles et al. 2008b; Bowles et al. 2020). Until monitoring was initiated under this protocol, managers in these parks had limited or no information about the status of their aquatic resources. The stream fish protocol addressed this informational deficiency and described methods for collecting fish community and habitat data (in-stream, riparian), in addition to diel CORE5 water quality data, in the parks previously not sampled under the prairie fish protocol. In total, the original stream fish protocol (version 1.0, Dodd et al. 2008) described monitoring of fish communities and their habitats in nine HTLN parks (EFMO, GWCA, HEHO, HOME, HOSP, PERI, PIPE, TAPR, WICR).

Modification of Fish Protocols

The prairie fish protocol (Peitz and Rowell 2004) focused on the Topeka shiner and its primary habitat in streams within TAPR and PIPE. While monitoring the status of the Topeka shiner is important, it is difficult to effectively monitor this species without extensive sampling effort. To document its status with confidence, it would be necessary to sample several times a year, particularly during breeding season when individuals are concentrated, and to track population dynamics with mark/recapture techniques. The sampling period for PIPE and TAPR (late August through October) was established to avoid the breeding season so the additional stress of sampling would not cause mortality among this already rare species. In an internal NPS memo summarizing the results of the prototype operation review (Gary Williams January 2002, personal communication), it was recommended that fish monitoring should be focused on the entire community and not a single species. In 2007, a proposal was submitted to and approved by the Board of Directors to refocus the prairie fish monitoring protocol to the collection of community data, rather than monitoring one individual species. In addition, this proposal added fish monitoring of seven HTLN parks that were not previously monitored.

The underlying objectives and sampling methods in the stream fish protocol (version 1.0) were refocused toward the collection of data for the entire fish community, and parks located in the Ozarks and Ouachita Mountains region and prairie parks of the Central Lowlands were added (Dodd et al. 2008). To accomplish these objectives, a reach-based approach similar to that used in other national-level protocols was employed and included (1) sampling all habitat types available within the stream reach, (2) collection of length and weight data on all fish species to develop a better understanding of community size structure and composition, (3) enhanced habitat collection to better characterize the streams and initiate water quality data-logging during fish sampling to evaluate diel patterns, and (4) retaining one representative downstream reach in each stream at TAPR (with the exception of one stream).

Information on relative abundance of Topeka shiner continued to be collected under the stream fish protocol, allowing comparison with historical data collected under the prairie fish protocol (Peitz and

Table 1. Rotational design for fish monitoring at TAPR and PIPE. F = full sample regime; A = abbreviated sample regime.

Park	Year								
	1	2	3	4	5	6	7	8	9
PIPE	F	A	A	F	A	A	F	A	A
TAPR	A	A	F	A	A	F	A	A	F

Rowell 2004). In addition, important information was collected on the entire fish community (richness, diversity, abundance, size structure, and composition), which interacts with and influences Topeka shiner populations. The stream fish protocol (version 1.0) also expanded the fish community monitoring program to seven additional parks not sampled under the prairie fish protocol (where only PIPE and TAPR were sampled). Details on modifications made to the prairie fish protocol are documented in version 1.0 of the stream fish protocol (Dodd et al. 2008) and in the Procedures for Protocol Revision section within this new protocol version (version 2.0).

Modifications in this version of the stream fish protocol (version 2.0) are related to changes in the revisit design for PIPE and TAPR. During the HTLN review in 2008, modifications to aquatic protocols were deemed necessary by Inventory and Monitoring Division staff, park superintendents, and resource managers because the HTLN aquatic staff was operating on a "razor-thin margin" in terms of workload (Fancy 2008). To address this concern, a proposal was written by the HTLN fisheries biologist in 2010 modifying the revisit design by placing TAPR and PIPE on a three-year rotation similar to the remaining seven parks sampled under version 1.0 of the stream fish protocol. This proposal was reviewed and approved by the Board of Directors as well as TAPR and PIPE resource managers in 2010. The proposal was published in Appendix A of DeBacker et al. (2012).

Annual fish monitoring at TAPR and PIPE will continue on an annual basis due to the parks' requirement to track the status of Topeka shiners but will be monitored at a reduced level (abbreviated regime) during certain years. TAPR and PIPE will be placed on a three year rotational panel (similar to the other seven small stream parks) whereby once every third year each park will receive the full sampling regime (fish, habitat, and water quality) described in this protocol (see Table 1 for scheduled years). This full sampling regime will coincide with the year in which aquatic invertebrate sampling is completed at the parks (Bowles et al. 2008b; Bowles et al. 2020). During full sampling years, all monitoring reaches at PIPE and TAPR will be sampled (Tables 1 and 2; Appendices 1 and 2) for fish community composition (including Topeka shiners) and size structure, as well as measurements of physical habitat and water quality. During the two off-cycle years, an abbreviated sampling regime will be completed (see Table 1 for scheduled years). Sampling will focus on obtaining fish community data at a subset of sample reaches that are of interest to the parks (one reach at PIPE, three reaches at TAPR; see Table 2). Habitat and water quality measurements will not be collected during years of abbreviated sampling in order to decrease the number of staff members necessary to complete sampling.

Measurable Objectives Addressed by the Protocol

Two broad objectives are addressed by this protocol.

1. Determine the status and long-term trends in fish richness, diversity, abundance, and community composition in small streams at EFMO, GWCA, HEHO, HOME, HOSP, PERI, PIPE, TAPR, and WICR.
2. Correlate the long-term community data to overall water quality and habitat condition (DeBacker et al. 2005).

Justification/Rationale for these Objectives: Until development of the stream fish protocol (version 1.0, Dodd et al. 2008), fish communities and their corresponding physical habitats and water quality had not been consistently inventoried or monitored in seven of the nine parks included in this protocol. With the exception of TAPR, the watersheds of these small streams remain largely unprotected, leaving them at risk to anthropogenic disturbance. Through long-term monitoring of these vulnerable aquatic resources, natural variability in fish communities,

Table 2. Reaches to be sampled during full (F) regime every third year and abbreviated (A) regime annually.

Park	Site	Year								
		1	2	3	4	5	6	7	8	9
PIPE	Lower	F	A	A	F	A	A	F	A	A
	Above Falls	F	–	–	F	–	–	F	–	–
TAPR	1 Lower	A	A	F	A	A	F	A	A	F
	1 Middle	A	A	F	A	A	F	A	A	F
	23 Middle	A	A	F	A	A	F	A	A	F
	2 Lower	–	–	F	–	–	F	–	–	F
	4 Middle	–	–	F	–	–	F	–	–	F
	10 Middle	–	–	F	–	–	F	–	–	F
	12 Middle	–	–	F	–	–	F	–	–	F
	17 Upper	–	–	F	–	–	F	–	–	F
	22 Lower	–	–	F	–	–	F	–	–	F
	24 Lower	–	–	F	–	–	F	–	–	F
	34 Lower	–	–	F	–	–	F	–	–	F
	35 Lower	–	–	F	–	–	F	–	–	F
	36 Middle	–	–	F	–	–	F	–	–	F

habitat, and water quality can be quantified such that trends or changes in these aquatic components can be used to support management decisions in the parks. The years of data collection under version 1.0 of this protocol along with available historical data from within the park or watershed will provide an estimate of natural variability among these populations and establish baseline conditions for the assessment of temporal changes and maintenance of stream integrity. Measuring water quality, habitat structure and availability, and watershed land use patterns and correlating these with fish community composition will allow insight into the relative influences these variables have on the integrity of these small stream ecosystems.

Operational Objectives

1. Communicate monitoring results to park natural resource managers, other park staff, and partners, including outreach efforts when appropriate. Furthermore, contributions to the scientific community may be valuable.
2. Conduct monitoring safely, ideally without accident or injury. Safe monitoring includes during transportation to/from parks as well as during field operations.

Sampling Design

Spatial Design

This protocol focuses on monitoring fish communities in wadeable streams distributed among nine HTLN parks. Sampling will be conducted at a single reach for each stream with the exception of PIPE and TAPR (see Tables 1 and 2 and Appendices 1 and 2). Greater sampling effort per stream is not possible due to limited budgets and resources in relationship to the relatively large number of target streams and parks sampled. Furthermore, most of the streams included in this protocol are relatively small, and the lengths of stream within the park boundaries are relatively short. An additional benefit of this approach is that it allows for monitoring fish communities in a greater number of network parks.

Sample Reaches

A sample reach is a section of stream that encompasses all channel units (riffles, runs, pools, glides) available within the stream, resulting in a representative fish sample. Some streams sampled under this protocol are characterized primarily by one or two channel unit types (pools and runs); therefore, only those channel units will be represented in the sample reach. For each stream, a sample reach will be established at the downstream end of the watershed within park boundaries. The rationale for this choice is that the further one goes downstream, the more representative the site is of the overall watershed. If reaches were selected randomly, sites could be located near the upstream park boundary, in which case they may be more representative of the stream and associated watershed above the park than within the park.

The location of the reach will be near the downstream park boundary for streams that flow outside of the park. For tributary streams that intersect larger streams within the park, reaches will be located near the confluence (but out of the floodplain) of the larger stream. The exact location of each reach will be based on availability of water for sampling, safety of personnel, accessibility, and ability to co-locate sites for other vital signs monitoring (i.e., aquatic invertebrates). Locating reaches based on the ability to sample effectively and safely is consistent with other national-level guidance (Moulton et al. 2002).

Parks Sampled Under Prairie Fish Protocol

At PIPE, TAPR, and HOME, reaches were established during fish sampling conducted under the prairie fish protocol (Peitz and Rowell 2004). Location of these reaches and reach length was based on the ability to find areas of the stream with adequate water to collect fish from five pools. Reaches that were included in the prairie fish protocol that have been observed to be consistently dry were removed from further consideration in version 1.0 of the stream fish protocol and the most downstream reach on each stream was retained for sampling (Dodd et al. 2008 and Table 3). In addition, one historical reach at both PIPE and TAPR not located at the downstream end of the watershed was retained due to differences in water quality and habitat conditions at PIPE and due to the site at TAPR being of special interest for fish community monitoring. Continuing to sample the retained reaches in the stream fish protocol allowed for comparability with historical data collected under the prairie fish protocol at these same reaches. In this version of the stream fish protocol (version 2.0), we will continue to sample these retained reaches (Tables 2 and 3 and Appendices 1–3). All retained reaches in the parks will be sampled on a three-year rotation (Tables 2 and 3). However, only a subset of retained reaches at PIPE (one reach) and TAPR (three reaches) will be sampled annually during abbreviated sampling (Table 2).

Additional Parks Sampled Under Stream Fish Protocol

Sampling reaches for streams within EFMO, GWCA, HEHO, HOSP, PERI, and WICR were established to satisfy specific requirements necessary to obtain a representative and unbiased sample. The downstream end of the reach was determined *a priori* and located as close to the downstream park boundary as possible or located just upstream of the floodplain for tributaries that flow into larger streams within the park. Reach length was defined as 20 times the mean wetted stream width (MWSW), allowing inclusion of representative channel units (riffle, run, and pool habitats) located within the stream (Moulton et al. 2002). This reach is a permanent sampling site, barring dramatic alterations in channel morphology that would require relocation of the sampling reach.

Table 3. Sample reaches retained in the stream fish protocol for PIPE, TAPR, and HOME along with UTM coordinates (NAD83 [Conus], Zone 14 N). All reaches are sampled every third year for fish, habitat and water quality.

Park	Reaches Sampled in Prairie Fish Protocol	Reaches Retained in Stream Fish Protocol	UTM (Northing, Easting)
PIPE	Pipestone Creek Lower	Lower	4877259.61, 714204.77
	Pipestone Creek Above Falls	Above Falls	4877060.11, 714772.31
TAPR	01 Lower	Lower	4257009.20, 713468.40
	01 Middle	Middle	4257264.29, 713122.37
	02 Lower	Lower	4256214.78, 713417.68
	04 Middle	Middle	4254966.47, 713101.21
	10 Middle	Middle	4254565.19, 715113.34
	12 Middle	Middle	4255010.98, 718023.53
	17 Upper	Upper	4263400.48, 710480.77
	22 Lower	Lower	4259710.35, 713002.62
	23 Middle	Middle	4257614.80, 709898.14
	24 Lower	Lower	4253659.26, 710868.26
	34 Lower	Lower	4263286.45, 709866.69
	36 Middle (Palmer Creek)	Middle	4263176.10, 710907.56
	35 Lower (Fox Creek)	Lower	4256985.51, 713944.53
HOME	Cub Creek Lower	Lower	4462337.67, 684059.84

Table 4. Streams sampled at EFMO, GWCA, HEHO, HOSP, PERI, and WICR and UTM coordinates for the downstream end of the sample reach (NAD83 [Conus], Zone 15 N).

Park	Streams Sampled	UTM (Northing, Easting)
EFMO	Dousman Creek	4772312.855, 645346.607
GWCA	Carver Creek	4094397.977, 379278.555
	Harkins Branch	4094541.749, 378983.421
	Williams Branch	4094438.178, 379192.791
HEHO	Hoover Creek	4614460.713, 637614.936
HOSP	Bull Bayou	3819370.096, 489900.19
	Gulpha Creek	3820624.347, 496761.701
PERI	Pratt Creek	4033226.941, 406996.977
WICR	Skegg's Branch	4105779.553, 463356.849
	Terrell Creek	4104000.832, 462818.328
	Wilson's Creek	4104427.268, 464032.61

Because GWCA and WICR also have long-term invertebrate monitoring, fish reaches were co-located with the downstream most historical invertebrate sites in these parks. See Table 4 for a list of streams sampled at these parks. Maps of sample reaches in these parks are located in Appendices 4–9.

Temporal Design

The fish community, habitat, and water quality are monitored at all stream reaches within PIPE (reaches = 2; Appendix 1) and TAPR (reaches = 13; Appendix 2) every third year under the full sampling regime (Tables 1–3 and 5). At these two parks, a subset of stream reaches are sampled annually under an abbreviated sampling regime where only fish community data are collected (Tables 1–2 and 5). Sampling will be done from late August through September to avoid the Topeka shiner breeding season. This approach is consistent with the prairie fish protocol (Peitz and Rowell 2004) and version 1.0 of the stream fish protocol (Dodd et al. 2008) to allow comparisons with the historical data.

Fish community, habitat, and water quality are monitored (i.e., full regime monitoring) in parks without documented Topeka shiner populations—EFMO, GWCA, HEHO, HOME, HOSP, PERI, and WICR—once every three years (Table 5). The index period of sampling is based on the period of low flow conditions and co-visitation for invertebrate sampling.

Response Design

Fish

Fish community data will be used to assess overall stream quality and biotic integrity of these small streams. At PIPE, TAPR, and HOME fish collection methods are the same as those described in the stream fish protocol, version 1.0 (Dodd et al. 2008), which generally follows the prairie fish protocol (Peitz and Rowell 2004) to allow for comparisons with historical data. Collection of fish data at EFMO, GWCA, HEHO, HOSP, PERI, and WICR is the same as those in version 1.0 of this protocol and follows the methods described in "Methods for Monitoring Fish Communities of Buffalo National River and Ozark National Scenic Riverways in the Ozark Plateaus of Arkansas and Missouri" (version 1.0, Petersen et al. 2008; version 2.0, Dodd et al. 2018). Within each reach, data on the entire fish community will be collected including community composition (species richness and percent composition of each species), abundance (catch per effort), size structure (lengths and weights), and overall health (occurrence of diseases and anomalies). Fish collection and processing techniques are described in SOP 4 (Fish Community Sampling) and details on parameters used to assess biotic integrity are discussed in SOP 9 (Data Analysis).

Habitat and Water Quality

Habitat incorporates all aspects of physical and chemical constituents and their interactions. Habitat composition within a stream is an important component in shaping aquatic communities. The type and abundance of specific habitats (e.g., riffles, pools, woody debris, etc.) will influence species presence and relative abundance, as well as size structure, of the populations. Because of its importance, physical habitat data will be collected as part of this protocol to examine relationships between environmental conditions and fish communities. Variables such as current velocity, substrate size, embeddedness, water chemistry, and presence of periphyton, filamentous algae and aquatic plants play key roles in the microhabitat structure and distribution of fish. Other habitat variables such as woody debris, boulders, canopy cover, and bank condition (e.g., height, angle, dominant substrate, degree of undercut, and vegetative cover) are also important for assessing stream

Table 5. Revisit design and index period for fish monitoring in small streams of HTLN. F = full sampling regime where all reaches are sampled for fish, habitat, and water quality. A = abbreviated sampling regime where only fish community data are collected at a subset of reaches in PIPE and TAPR.

Study Park	Index Period	Year								
		1	2	3	4	5	6	7	8	9
PIPE	Aug–Sep	F	A	A	F	A	A	F	A	A
TAPR	Aug–Sep	A	A	F	A	A	F	A	A	F
GWCA	May–June	F	–	–	F	–	–	F	–	–
WICR	May–June	F	–	–	F	–	–	F	–	–
EFMO	July–Aug	–	F	–	–	F	–	–	F	–
HEHO	July–Aug	–	F	–	–	F	–	–	F	–
HOME	Aug–Sep	–	F	–	–	F	–	–	F	–
PERI	May–June	–	–	F	–	–	F	–	–	F
HOSP	June–July	–	–	F	–	–	F	–	–	F

condition. All the aforementioned habitat variables will be monitored at our sampling reaches. For details on sampling physical habitat and water quality, see SOP 5 (Physical Habitat Measurements) and SOP 3 (Documenting CORE 5 Water Quality Variables).

Rationale for the Sampling Design

Biomonitoring methodologies are constantly being developed and refined in an effort to achieve the most efficient and effective assessments of water quality, physical habitat, and fish communities. Several different sampling approaches or protocols have been used by state and federal agencies to quantify status and trends of fish communities in streams. Rapid Bioassessment Protocols (RBPs) developed by the US Environmental Protection Agency (USEPA) have been used by many agencies to evaluate fish communities in streams (Barbour et al. 1999). These protocols are designed to give a quick, broad picture of stream quality and fish assemblages throughout a region with minimal field and laboratory efforts. Additional and commonly used monitoring protocols include the EPA Environmental Monitoring and Assessment Program (EMAP) protocols for wadeable streams (Lazorchak et al. 1998; McCormick and Hughes 1998) and the USGS NAWQA protocols (Moulton et al. 2002). In comparison to the RBPs, these latter two protocols involve more rigorous data collection (i.e., collection of fish lengths and weights) and quantitative methods (i.e., designated reach length), giving a more complete picture of fish assemblage composition and structure.

The many streams monitored in this protocol are located in different physiographic regions (Central Lowlands, Ozark Plateaus, and Ouachita Province) with varying stream geomorphology, sediment composition, and riparian vegetation. Therefore, this stream fish protocol (both version 1.0 and this version 2.0) is a combination of the prairie fish protocol (Peitz and Rowell 2004) established for softer sediment prairie streams and the HTLN fish protocol established for Ozark rivers and tributaries with larger sediment (version 1.0, Petersen et al. 2008; version 2.0, Dodd et al. 2018). To maintain comparability with historical monitoring data at PIPE, TAPR, and HOME, a modified version of the prairie fish protocol will be used. These modifications bring this prairie fish protocol in line with other national-level protocols (NAWQA and EMAP) by focusing on the entire community and sampling all available habitats throughout the reach.

The sampling approach described in this protocol for EFMO, GWCA, HEHO, PERI, HOSP, and WICR is based on methods in the HTLN Ozarks river fish protocol, a modified NAWQA protocol. It was necessary to modify the NAWQA fish protocol for both this protocol and the HTLN Ozarks river fish protocol to meet specific objectives of the HTLN long-term monitoring program. Reach selection in this protocol is similar to that of tributaries sampled under the HTLN Ozarks river fish protocol in that one reach per stream is sampled at the downstream end of the watershed due to the relatively short length (≤3 km) of all the streams included in this protocol. The one difference in reach selection between this protocol and the HTLN Ozarks river fish protocol is that the downstream boundary of the reach is based on professional judgment and co-location with other monitoring programs (similar to NAWQA reach selection methods); whereas, the HTLN Ozarks river fish protocol uses location of the second riffle upstream of the river floodplain for establishing the reach boundary of wadeable tributaries. Because some of the streams under this protocol have primarily run/pool morphology, we can not use location of riffles to establish the downstream reach boundary for all streams in all parks.

Field and Laboratory Methods

Field Season Preparations, Field Schedule, and Equipment Setup

Procedures for field season preparations, including preparation of a field sampling schedule and equipment setup, are described in SOP 1 (Preparation for Field Sampling). The project leader (fisheries biologist) will ensure that team members have read and understand the protocol and supporting SOPs prior to sampling and, with the help of the aquatic ecologist, ensure that all required equipment and supplies have been ordered and are in proper working condition. Fieldwork must be scheduled in advance so that crews can be assigned. Training team members on use of fish sampling and water quality meters will be completed prior to field work (see SOP 2, Training). Time spent at a sampling reach will vary, but anywhere from 2–4 hours per reach is typical. Sampling period will vary depending on the park to be sampled (see index period in Table 5). The project leader or crew leader (i.e. aquatic ecologist) will prepare and maintain a field notebook detailing all sampling-related activities and staff participation during monitoring trips to ensure that trip reports are complete and accurate. Finally, the project leader will ensure that all required scientific collection permits have been obtained.

Collecting Fish Samples

At PIPE, TAPR, and HOME, fish community data will be collected at three to five sites (channel units) within each sample reach using a minnow seine (Figure 1). Single pass electrofishing methods will be employed throughout each sampling reach at EFMO, GWCA, HEHO, HOSP, PERI, and WICR (Figure 2).The size of the stream (width and depth) will determine the size of seine used or the type of electrofishing gear used (tow barge versus backpack electrofisher). Associated habitat and water quality will be measured in conjunction with fish sampling at all parks.

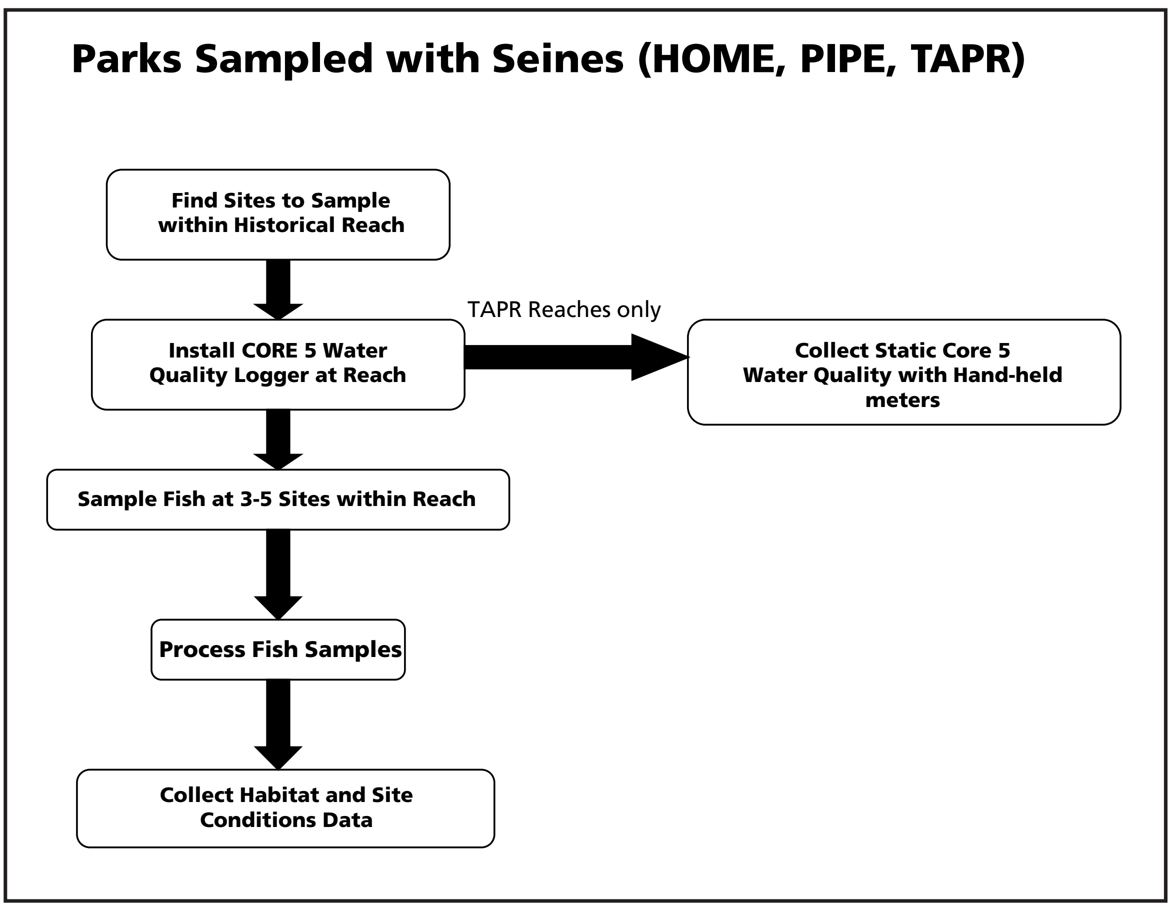

Figure 1. Flow of work diagram for parks sampled by seining under the prairie fish protocol (PIPE, TAPR, HOME).

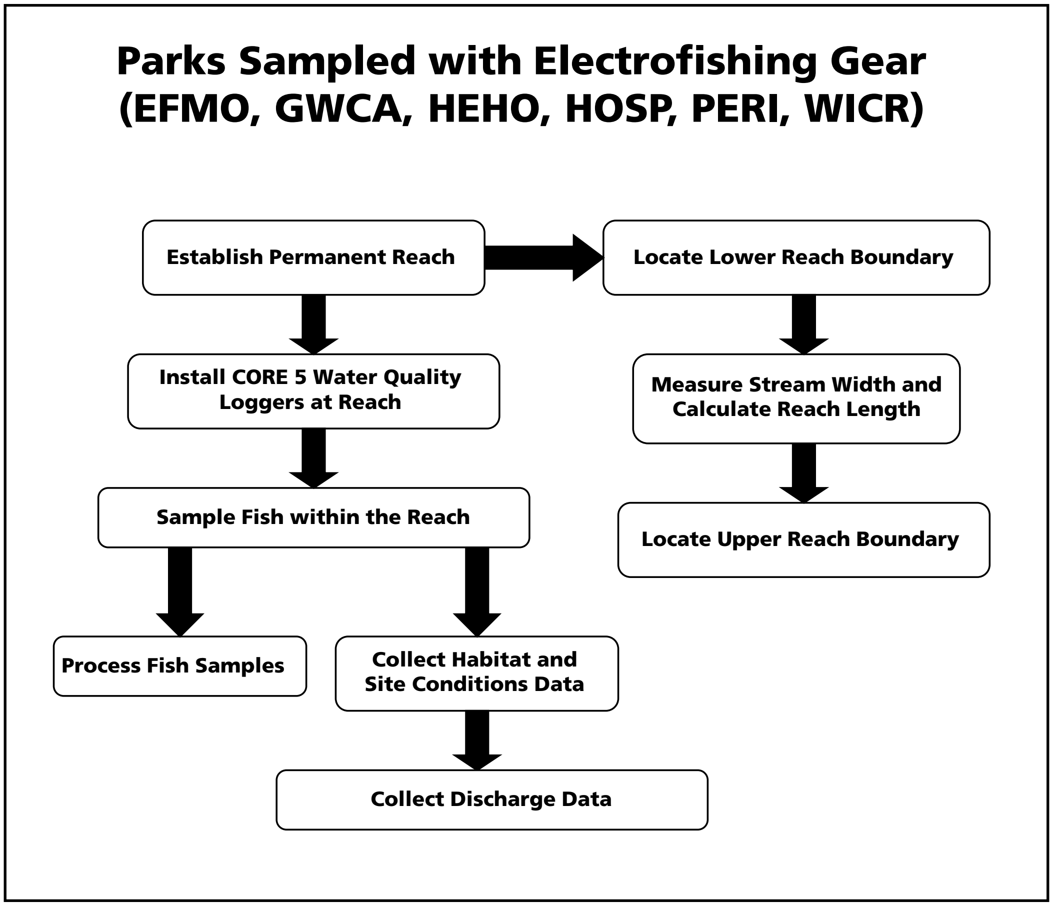

Figure 2. Flow of work diagram for parks sampled with electrofishing methods (EFMO, GWCA, HEHO, HOSP, PERI, WICR).

When monitoring, it is important to note that gear type and efficiency have been shown to affect fish community sampling data quality. In a study of fish data from 55 NAWQA sites, Meador and McIntyre (2003) found that among electrofishing methods (backpack, towed barge, and boat), Jaccard's (similarity) index and percent similarity index values between years and between multiple reaches were significantly greater for backpack electrofishing. These results suggest that data collected using different gear types (or different combinations of multiple types of gear) may be subject to considerable variability. Because this protocol is concerned with monitoring temporal changes within each stream reach rather than comparing across streams that may have been sampled using different gears, it is imperative to maintain consistency among gear type and sampling effort in the reaches across years (see Table 6).

During sample processing, the gear used, time spent sampling, length of the reach or site sampled, and species data will be recorded. To the extent practical, individual specimens will be identified to species in the field using appropriate fish identification keys and other relevant information. Specimens that cannot be reliably identified in the field will be preserved for later identification in the laboratory (see SOP 4). Individual lengths and weights will be collected on a subsample of each species at a reach to estimate the size structure and community composition. Anomalies will also be recorded to determine the occurrence of diseases and deformities in the fish populations.

Measuring CORE 5 Water Quality and Physical Habitat

CORE 5 water quality parameters (temperature, dissolved oxygen, specific conductance, pH, and turbidity) will be recorded using a data logger or sonde at each reach. The data logger will be deployed in or near the sampling reach and allowed to operate for a minimum of 48 hours. Instructions for using the datalogger are located in SOP 3 (Documenting CORE 5 Water Quality Variables). Due to the large number of reaches at TAPR, deployment of

Table 6. List of stream reaches sampled for fish communities and list of gear used and percent effort by gear for each reach.

Park	Streams Sampled	Gear Type Used	% Effort by Gear
EFMO	Dousman Creek	Backpack Electrofisher	100
GWCA	Carver Creek	Backpack Electrofisher	100
	Harkins Branch	Backpack Electrofisher	100
	Williams Branch	Backpack Electrofisher	100
HEHO	Hoover Creek	Backpack Electrofisher	100
HOME	Cub Creek	Seine	100
HOSP	Bull Bayou	Backpack Electrofisher	100
	Gulpha Creek	Backpack Electrofisher	100
PERI	Pratt Creek	Backpack Electrofisher	100
PIPE	Pipestone Creek	Seine	100
TAPR	12 streams	Seine	100
WICR	Skegg's Branch	Backpack Electrofisher	100
	Terrell Creek	Backpack Electrofisher	100
	Wilson's Creek	Towed Barge Electrofisher	100

data loggers at each reach is not practical, and static CORE 5 will be taken at sampling sites within the reach using hand-held meters. However, data loggers will be deployed at selected reaches at TAPR to collect continuous data. Discharge will be measured only at reaches sampled by electrofishing gear. Instructions for measuring stream discharge are in SOP 6 (Measuring Stream Discharge).

Habitat composition will be measured in conjunction with fish sampling. For PIPE, TAPR, and HOME, methods are modified from Peitz and Rowell (2004). For the remaining parks, habitat methods follow methods described in the Ozarks river fish protocol (Petersen et al. 2008; Dodd et al. 2018). For all nine parks, physical habitat is assessed at transects perpendicular to flow. At each transect, several physical attributes will be measured including width, depth, velocity, in-stream substrate, bank erosion/stability, and riparian cover. See SOP 5 for details on habitat collection methods.

Sample Storage and Reference Collection

A reference collection of identified fish species is kept at the NPS HTLN office located at Missouri State University, Springfield, Missouri. All other fish collected during monitoring will be returned to the streams from which they were collected or disposed of properly.

Post Season Procedures

Procedures for the end of the sample season are found in SOP 7 (Equipment Storage and Maintenance).

Data Management

Data management procedures are an important part of any long-term monitoring program in that they provide data consistency, data security, and availability over time. Therefore, care must be taken to ensure that adequate time and personnel are available for accurate data recording, data entry and verification, and analysis. At the core of this data management is the monitoring database organized by primary and ancillary data.

Primary data consist of reach identification and site description, sampling personnel, sampling date, sampling time, equipment description, sampling duration, and fish community data. Examples of ancillary data records include identification of various environmental characteristics.

Data processing typically involves the following steps: data entry, data verification, data validation and backups/storage (see SOP 8 for details on each step). Data entry consists of transferring field data from field sheets into a monitoring database using data-entry forms. Data verification immediately follows data entry and involves checking the accuracy of computerized records against the original source, usually paper field records. Validation procedures seek to identify generic errors, such as missing, mismatched, or duplicate records, as well as logical errors specific to particular projects. Spatial validation of location coordinates can be accomplished using a Global Navigation Satellite System (GNSS). Global Positioning System (GPS) points are validated against DRGs (digital raster graphic files) or DOQQs (digital ortho-quarter quadrangles) for their general location.

Frequent backups are critical for preventing loss of long-term data. Full backup copies of the monitoring project are stored at an off-site location for safe keeping. Additional digital copies are forwarded to the NPS IRMA Data Store System.

Overview of Database Design

There is one database that contains all fish community data (and related habitat and water quality data) collected by HTLN. Under version 1.0 of the small streams fish protocol (Dodd et al. 2008), all biotic and abiotic measurements collected for the nine parks with wadable streams were entered into one database. A separate database was maintained for the Ozarks river fish protocol (Petersen et al. 2008; Dodd et al. 2018) and for fish community data for the springs community protocol (Bowles et al. 2008a). Because the fish sampling methodology and field forms for electrofished parks in the small streams fish protocol are the same as those in the Ozarks river fish and spring communities protocols, all fish data are now located in one common fish community database. The general data model consists of two core sets of tables. These two core tables contain general information pertaining to the field sampling occasion (the when and where of the sample). This includes information such as date and time, location, and park/project codes. The taxa-related tables serve as the organizing hub for taxa data. Other tables primarily address habitat or water quality conditions. The database also documents the protocol version and QA/QC results. All data management activities related to this protocol are described in SOP 8 (Data Management).

Quality Assurance and Quality Control

Quality Assurance (QA) includes all activities designed to ensure that data, products, or services meet specified requirements. Quality Assurance focuses on building-in quality to prevent defects. Quality Control (QC) includes procedures for checking whether data meet standards and annotating or qualifying data that do not (DeVivo 2016).

Quality Assurance (QA) and Quality Control (QC) procedures and design elements occur throughout data collection, processing, and reporting and are addressed in the SOPs.

The database design includes fields to document the completion and results of QA/QC procedures and assessments.

- The Inventory and Monitoring Division Database Standards (Frakes et al. 2015) document requires every datum to be unambiguously traceable to a specific version of a monitoring protocol, a quality assurance plan (QAP) where available, and suite of standard operating procedures (SOPs).
- The certification guidelines for I&M data products (NPS 2016), and Minimum Implementation Standards for Network Projects v. 3.0 (Frakes

and Kingston 2017) calls for every datum to have an associated QA/QC processing level (e.g., raw, provisional, certified)

- An annual operational review is required for all active monitoring protocols (Mitchell et al. 2018). Completion of an operational review, a summary of any flagged data, and a link to the review report are stored in the monitoring database.

Metadata Procedures

The Federal Geographic Data Committee (FGDC) now provides a range of options as guidance for metadata of spatial and non-spatial federal agency data. Most recommendations are variations of the ISO191xx standard which is typically used for natural resource datasets. Creation of ISO metadata has been greatly facilitated by ESRI ArcGIS utilities that automatically generate spatial metadata. Once metadata are created, they should be saved in XML format following ISO metadata standards. Metadata are archived in the geodatabase and by WASO I&M (IRMA). Metadata are archived by WASO with the submission of the monitoring protocol. Metadata will be updated with each protocol revision.

Data Archival Procedures

HTLN archives all spatial and non-spatial data (including tabular documents) on a weekly basis. Backups are incremental rather than mirrored so that files are never overwritten. Permanent data archives are created on a quarterly and annual basis and stored offsite in a bank safe box.

Like other monitoring databases/geodatabases, the fish database is stored and secured by file archives stored on the server. The databases are maintained under a directory named the heartlandcommon production drive. The database immediately below this directory is the production copy of the database. All backups are incremental rather than mirrored so that all earlier versions are stored under this directory.

Annually, in fulfillment of the Data Analysis and Reporting Requirements (Gallo, K. memorandum dated 4/23/2018), the fish database will be uploaded to the IRMA DataStore. The dataset is flagged as “read only" for all users except the Project Leader and Data Manager. Because the fish database contains information on the endangered Topeka shiner, those records are not included in the uploaded dataset.

Analysis and Reporting

Analysis

In any long-term monitoring program, a consistent methodology and careful implementation of field sampling techniques are critical in obtaining comparable data. Thus, the procedures for data collection must be specified and followed exactly. In contrast, data analysis techniques do not need to be specified in as much detail. Many different analysis methods are available and are documented in great detail in texts and literature. Moreover, new methods are developed over time. Thus, absolute and detailed specification of data analysis techniques is not necessary or desirable. Due to the complexity of higher-level analyses, many options are available and step-by-step instructions will not be sufficient; a competent analyst will always need to be consulted. Thus, descriptions of various data analysis options are presented here and in SOP 9 (Data Analysis), realizing that the most appropriate techniques will vary over time as sample sizes increase, and that the details of any analysis can be found in the relevant texts or literature.

The data analysis process needs to be flexible enough to allow the use of newly developed statistical and analytical techniques and tailoring of analyses for a variety of audiences. In determining the appropriate statistical approaches for this monitoring protocol, it is crucial to consider the primary audience of the various reports that will result. The primary audience for brief data summaries of short-term data sets (less than 5 years) or data updates of longer-term data sets (addition of 1 or 2 data points to a data set that has more than 5 years of data) will consist of park resource managers, superintendents, interpretive staff, and potentially park visitors. More in-depth data summaries or trend reports of longer-term data sets (more than 5 years) will target park resource managers, superintendents, and outside agency partners as the primary audience. Additionally, protocols, such as this one, provide a large amount of data on many different types of variables. Thus, to the extent possible, it is important that core data analyses and presentation methods are relatively straightforward to interpret, provide a standard format for evaluation of numerous variables, can be quickly updated whenever additional data become available, and work for many different types of indicators, whether univariate or multivariate. The type and magnitude of variability or uncertainty associated with the results should be measurable, allowing thresholds to be established for potential management action. In addition to core analyses described in this protocol, future resource questions posed by park staff may warrant issue-specific analyses of certain fish or habitat parameters (DeBacker et al. 2012).

There are four main statistical approaches that can be employed with data from long-term monitoring projects: (1) testing hypotheses, (2) estimating biological characteristics or metrics, (3) multivariate analyses, and (4) applying Bayesian methods. When analyzing ecological data, statisticians predominantly employ frequentist methods, and thus many resource managers are not familiar with the interpretation of Bayesian approaches. Furthermore, Bayesian methods are not widely used because they are often difficult to apply, and many researchers are not comfortable specifying subjective degrees of belief in their hypotheses (Utts 1988; Hoenig and Heisey 2001). Thus, we do not advocate a Bayesian approach.

We monitor to detect changes in fish communities, but we are more specifically interested in the magnitude or direction of change and whether it represents something biologically important. For hypothesis testing, concern should be placed on whether the data support meaningful scientific hypotheses that are biologically significant (Kirk 1996; Hoenig and Heisey 2001). Depending on the characteristics of the ecological data being analyzed (i.e. normal distribution, data independence, etc.), parametric (e.g. linear regression, univariate control charts) and non-parametric (e.g. Mann-Kendall; Mann 1945; Kendall 1975) tests may be warranted to detect a directional change or an abrupt change in the fish community due to changes in park management strategies or changes in adjacent land use.

Estimation of biological characteristics or metrics (hereafter referred to as "metric estimation") is a straightforward method that can provide more information than hypothesis testing (Steidl et al. 1997; Gerard et al. 1998; Johnson 1999; Anderson et al. 2000, 2001; Colegrave and Ruxton 2003; Nakagawa and Foster 2004). Metric estimation emphasizes the magnitude of effects and the biological significance of the results (Shaver 1993; Stoehr 1999). There is no formal classification of error associated with metric estimation. One of the primary recommendations from a workshop on environmental monitoring organized by the Ecological Society of America was that trend studies should focus on description of trends and their uncertainty rather than hypothesis testing (Olsen et al. 1997). Thus, most of the data analysis suggested in this protocol will take the form of metric estimation.

Metrics have been used to detect trends in fish communities and investigate the relationships between fish communities and environmental conditions. Two common approaches are calculation of individual metrics and calculation of multiple-metric biological indexes (Plafkin et al. 1989; Hughes and Oberdorff 1998; Barbour et al. 1999; Simon 1999). Biological metrics are commonly used by scientists to compare the condition of the biological community at multiple sites (Simon 1999) or across time. A metric is a characteristic of the biota that changes in a predictable way with increased human disturbance or stream recovery from disturbance (Barbour et al. 1999). Attributes of the fish community such as degree of tolerance to disturbance, habitat and substrate preferences, spawning preferences, and trophic status are measures frequently reflected in metrics making it possible to determine relationships between biological communities and environmental conditions.

An extension of the metric approach is to combine multiple metrics into an Index of Biotic Integrity (IBI) by the scoring and summing of individual metrics. A standardized scoring criterion is developed for specific regions or watersheds. This index is used as an indicator of overall stream quality, enabling investigators to compare conditions at multiple sites across a region/watershed or at a single site across time (Karr 1981; Barbour et al. 1999; Simon 1999). IBIs have been created for Ozark Highland streams (Hoefs 1989; Dauwalter et al. 2003; Matt Combes, Missouri Department of Conservation, written comm., 2006) and three ecoregions in Arkansas (Hlass et al. 1998 ; Dauwalter et al. 2003; Justus 2003; Dauwalter and Jackson 2004). Prior to use of fish communities as bioindicators, aquatic invertebrate communities were, and still are, used as indicators of stream quality (Hilsenhoff 1977). Because of the popularity of fish with the general public and stakeholders, fish communities are the most commonly used bioindicator for investigating ecological relationships using the IBI approach (Barbour et al. 1999; Simon 1999).

Multivariate analyses are another commonly used statistical method to explain variability in community data and attribute that variability to specific environmental variables or gradients (Gauch 1982; Jongman et al. 1995; Petersen 1998; Everitt and Dunn 2001; Timm 2002; Petersen 2004). Multivariate techniques differ from univariate or bivariate analyses in that the former techniques are generally more descriptive and generate hypotheses from the biological data rather than attempt to disprove a null hypothesis, and the effectiveness improves as the number of variables increase (Williams and Gillard 1971). Two multivariate techniques commonly used to analyze community data include ordination and classification (Gauch 1982; Jongman et al. 1995; Everitt and Dunn 2001; McCune and Grace 2002; Timm 2002).

Control charts can also be employed in data organization and analysis. Control charts, developed for industrial applications, indicate when a system is going *out of control* by plotting through time some measure of a stochastic process with reference to its expected value (Beauregard et al. 1992; Gyrna 2001; Montgomery 2001; Morrison 2008). Control charts may be univariate or multivariate and can be used for different types of variables (i.e., metrics, count, or frequency data). Control charts have been applied to ecological data (McBean and Rovers 1998; Manly 2001), including fish communities (Pettersson 1998; Anderson and Thompson 2004) and natural resources within the NPS inventory and monitoring program (Atkinson et al. 2003). Control charts contain control limit(s) specifying thresholds beyond which variability in the indicator (estimated metric) reveals a biologically important change is occurring and warns that management may need to act. Control limits can be set using a desired confidence interval around the data, a desired management goal, or a regulatory threshold for the metric of interest.

A formal power analysis for this protocol was not conducted for three reasons (Morrison 2007). First, the primary purpose of conducting a prospective power analysis is to determine whether the proposed sample size is adequate. Because sample size for this monitoring program is determined primarily by budget and staff size, an increase in sample size is not possible regardless of the result of any power analysis. Furthermore, in many analyses sample size will equate with number of years; in this case, analyses will simply become more powerful over time. Secondly, statistical power is dependent upon the hypothesis under test and the statistical test used. Over the course of this long-term monitoring program, different questions will be of interest, and various hypotheses could be evaluated. Thus, there is no single *power* relevant to the overall protocol. Estimating power at this point in the context of such a long-term, multifaceted monitoring program could be potentially misleading, as the test this power is based upon may rarely (or never) actually be employed. Lastly, most data analyses will take the form of metric estimation, rather than null hypothesis significance testing. When estimating metrics, there is no associated statistical power and alternative approaches to measuring the variability or uncertainty in the data will be employed, when applicable.

The primary approach to organizing and analyzing data will consist of metric estimation combined with trend analysis (parametric or non-parametric), the use of control charts, and multivariate techniques such as ordination or classification. However, the use of other statistical methods cannot be ruled out at this time. Because of the nature of this long-term monitoring program, other approaches (some of which may not have even been developed yet) may be appropriate at different points in time, depending upon the needs of the resource managers and questions of interest. Specific resource questions by park staff may require use of hypothesis testing using either parametric or non-parametric tests depending on the normality and the independence of the data set analyzed. Tests for normality and spatial or temporal autocorrelation should be performed to determine the validity of using parametric tests. Employing multiple analytic approaches will provide multiple lines of evidence on trends or patterns in fish communities within the park, increasing the validity and confidence of study conclusions. A detailed summary of calculated metrics and data analysis techniques are given in SOP 9 (Data Analysis).

Reporting

Reports and updates should be completed the calendar year in which the data were collected and should include an informal trip report and an operational review report. Brief updates of the data may be in the form of a resource brief, web article, or data visualizer. Trend reports are updated every six to nine years (2 or 3 sampling cycles). Trend reports explore correlations among the data over time. Trend reports are published as Natural Resource Reports in the NPS Natural Resource Reporting Series and uploaded to IRMA or published in peer-reviewed scientific literature. Refer to SOP 10 (Data Reporting) for details on reporting. Results from fish community monitoring will be distributed to park superintendents and resource management staff. Collector's reports to the USFWS and state agencies (as a requirement for scientific collector's permits) will be submitted annually.

Personnel Requirements and Training

Roles and Responsibilities

The project manager is the fisheries biologist for the HTLN and this person bears responsibility for implementing this monitoring protocol. Because consistency is essential to implementation of the protocol, the project manager will usually lead field data collection efforts unless technicians have several years of experience collecting the data related to this protocol as determined by the project manager. Critical to the success of a monitoring program is a high level of consistency in field collection and data analysis from year to year. To obtain this consistency, it is necessary to have a competently trained staff and, preferably, the same staff every year. For the field crew, the fisheries biologist (project manager) and aquatic ecologist(s) will remain relatively consistent from year to year. The project manager is responsible for ensuring that, with assistance from the aquatic ecologist(s), all crewmembers are trained. Training should be done prior to each field season with each crewmember reviewing the SOPs outlined in this protocol. Training should include discussions with crewmembers on safety protocols for fieldwork (SOP 2, Training), demonstrations on proper use of water quality meters (SOP 3, Documenting CORE 5 Water Quality Variables), GPS units, and electrofishing/seining equipment (SOP 4, Fish Community Sampling), and practice of proper sampling techniques.

The personnel required to conduct fish community sampling depends on several variables including those related to safety, accessibility, and stream size. Safety, stream size, and time considerations largely determine how many personnel are necessary for fish sampling, particularly when site access is poor (because poor site access may require a larger crew). Smaller wadeable sites require two to three people, while larger wadeable sites require a minimum of five to six. The crew will be made up of at least one member (i.e., fisheries biologist or aquatic ecologist) who has experience leading and training a field crew and familiarity with site locations and the fish and habitat SOPs. For those parks where electrofishing will be employed, at least two crewmembers should be familiar with electrofishing (see SOP 2 for specific qualifications of crew members). For safety of the crew, at least one member of the crew (HTLN fisheries biologist or aquatic ecologist or other technician) must have successfully completed the USFWS electrofishing course. It is highly recommended that two crew members complete the USFWS electrofishing course, if possible.

The project manager will oversee all laboratory work including all QA/QC requirements. The program aquatic ecologists will assist the project manager with field collection and laboratory processing, equipment maintenance, purchasing of supplies, and sample storage. The fisheries biologist (or one of the aquatic ecologists with skills in taxonomic identification) will be responsible for identifying fish to the species level in the field and the laboratory.

In addition to implementing the monitoring, the project manager, in collaboration with the data manager, is responsible for managing the collected data. The project manager (fisheries biologist) will be responsible for ensuring data collection and entry, data verification and validation, and data analysis and reporting. The data manager is responsible for database design and modification, archiving and securing the data, and dissemination of the data. The data manager is also responsible for constructing adequate quality assurance/quality control (QA/QC) procedures and automating report generation based on the project manager's analysis needs.

Qualifications and Training

Training is an essential component for collecting credible data. Training for consistency and accuracy should be emphasized for both the field and laboratory aspects of the protocol. SOP 2 (Training) describes the training requirements for new technicians. The project manager and aquatic ecologist(s) should oversee this training and ensure that each technician/intern is adequately prepared to collect data. Taxonomic identifications for fish may be performed by a technician with several years of experience, but initial identifications should be checked by expert taxonomists.

Operational Requirements

Annual Workload and Field Schedule

Samples will be taken once a year at PIPE and TAPR (abbreviated sample regime every year and full regime every third year) and once every three years for EFMO, GWCA, HEHO, HOME, HOSP, PERI, and WICR (see Tables 2 and 5). Sampling at each park should begin approximately at the same time each year, and samples should be collected within the shortest time frame possible to minimize the effects of seasonal change. For fish monitoring a minimum crew of two to six will be needed depending on the gear used. For habitat sampling, a minimum of two people will be required, but three people make the process much more efficient. Typically, two to three reaches can be sampled in one day depending on ease of access and number of personnel.

Facility and Equipment Requirements

Field and lab equipment listed in SOP 1 (Preparation for Field Sampling and Laboratory Processing) are for only one sampling crew. Beyond normal office and equipment storage space, facility needs include access to a wet laboratory.

Startup Costs and Budget Considerations

Personnel expenses for fieldwork are based on a crew of two to six (fisheries biologist to oversee the field-work, one to two aquatic ecologists and two to three seasonal technicians to assist in field data collection). Assistance with field work from other agencies and park personnel is always welcome to the extent it is available. Field costs may vary somewhat from year to year depending on the skill level and size of crew and based on travel distance to those parks sampled on a rotation. Data management personnel expenses include staff time of the fisheries biologist and data manager.

Procedures for Protocol Revision

Revision Procedures

The protocol narrative is a general overview on the background and justification for the monitoring project and an overview of sampling design and methodology. Revisions to the protocol narrative may be necessary for several reasons, such as changes in temporal design (how often sites are visited) or spatial design (what sites are visited). However, changes to the narrative will be infrequent. Documentation of protocol revisions is mandatory for maintaining consistency in data collection and analysis between the earlier and the revised version. The purpose for publishing the protocol narrative separately from SOPs is to organize the protocol such that minor changes to SOPs do not require a revision of the entire protocol. SOPs contain more detailed information on completing tasks required for monitoring and may need to be revised more frequently than the protocol narrative (see SOP 11, Revising the Standard Operation Procedures, for details on revising SOPs). Therefore, revisions to SOPs will not require revision of the protocol narrative unless major changes are made that affect study design or methodology.

All versions of the protocol narrative and SOPs must be archived in a protocol library on the NPS IRMA Data Store (https://irma.nps.gov/Portal). A protocol revision log will be maintained at the beginning of the protocol narrative giving an overview of changes made. Items recorded in the log include previous version number, revision date, person (author) revising the protocol, general changes made, reason for changes, and the new version number. A detailed history of changes to the protocol narrative will be maintained under this section (Procedures for Protocol Revision). This includes a running history of the protocol and changes made to specific sections of the narrative, justification for changes, and any references related to the justification for change (see Table 9 in the Revisions to Stream Fish Protocol section for examples). Once changes have been made, the version number of the Narrative will increase by 0.1 for minor revisions and by 1.0 for major revisions. Mitchell et al. (2018) describe the necessary review and documentation for modifying the protocol. See SOP 11 (Revising the Protocol SOP) for further details.

Revisions to the protocol will also be recorded in the fish community database under a field identifying the protocol version in use at the time of data collection. This will ensure that staff managing the data and running analyses are aware of revisions that may require changes in database design or analytical procedures. See SOP 8 (Data Management) for details on protocol traceability within the database.

Protocol Narrative Revision History

Modifications to Prairie Fish Protocol (Peitz and Rowell 2004)

Several key modifications to the prairie fish protocol (Peitz and Rowell 2004) are described in the stream fish protocol, version 1.0 (Dodd et al. 2008) that incorporate current scientific thinking. A summary of these changes can be found in Table 7 and in Dodd et al. 2008. In general, the changes increase sample efficiency and enhance data quality and quantity without compromising the use of historical data in analyses of newly collected data. Modifications to the prairie fish protocol are given below and taken from Dodd et al. (2008).

- Objectives were refocused to include monitoring the entire fish community rather than an individual species. Therefore, all available habitats and channel units within a reach were sampled.
- The protocol was expanded to include fish community monitoring in seven additional streams at six parks not previously sampled under the prairie fish protocol: EFMO, GWCA, HEHO, HOSP, PERI, and WICR.
- Historically, multiple reaches were sampled on streams at PIPE, TAPR, and HOME. This was changed to just one representative reach per stream sampled at all nine parks. However, two historical sites on Pipestone Creek at PIPE and two sites on stream 1 at TAPR were retained.
- Under the small stream fish protocol, PIPE and TAPR continued to be sampled annually, but the remaining seven parks changed to sampling on a three-year rotation.
- Seining continued to be the only means for sampling fish at PIPE, TAPR, and HOME. This approach was retained because seining is the most efficient method for the sandy bottom and turbid

Table 7. Changes made to the prairie fish protocol and incorporated in the stream fish protocol, version 1.0.

Change Made	Prairie Fish Protocol	Stream Fish Protocol (Version 1.0)
Objectives of monitoring	Topeka Shiner status	Fish Community
Channel units sampled	Pools	All available habitat
Number of parks	2	9
Sampling reaches	Multiple per stream	1 per stream
Sampling frequency	Annually	Annually for PIPE and TAPR; 3-year rotation for other parks
Sampling gear	Seine	Seine at PIPE, TAPR, HOME; Electrofishing at other parks
Fish community data	Topeka shiners measured; all other fish counted	A 30-specimen subsample of each species measured; remaining fish counted
In-stream habitat assessment	Single reading taken at middle of each pool sampled	Taken at 3 transects in each channel unit at PIPE, TAPR, HOME; 11 transects among entire reach at other parks
Velocity	Not collected	Collected at transects with flow meter and wading rod
Water quality	Static CORE 5 readings (hand-held meters)	Unattended hourly CORE 5 readings (datasonde)

water of Cub Creek (HOME), and it reduces stress on Topeka shiners at PIPE and TAPR. Retaining this approach has allowed comparisons with historical data collected under the original protocol.

- Fish collection methods for EFMO, GWCA, HEHO, HOSP, PERI, and WICR followed Petersen et al. (2008), which is based on the existing US Geological Survey National Water-Quality Assessment (USGS NAWQA) fish protocol (Moulton et al. 2002). The broad diversity of substrate composition and habitat conditions of streams in these parks required use of an electrofishing method.
- Under the prairie fish protocol, only Topeka shiners were measured and weighed while all other species were counted. Under the new protocol, length and weight were measured for a subsample of up to 30 individuals of each species at each sample reach.
- Previously, in-stream habitat data were collected only at a single data point in pools where fish were seined. At PIPE, TAPR, and HOME where seining methods are used, this was changed to assessing habitat at three transects within each channel unit (riffle, run, pool) sampled with one data point per transect (i.e., three data points per channel unit sampled). At the remaining parks where electrofishing methods are employed, the new protocol called for an 11-transect method within the entire reach (after Petersen et al. 2008). Additionally, current velocity was measured at each transect at each park.
- In lieu of static CORE5 water quality measurements that were collected historically at PIPE, TAPR, and HOME using hand–held meters, hourly water quality measurements will be collected at each sample reach within each of the eight parks using datasonde loggers. The one exception is TAPR, where data sondes will be used at a subset of sample reaches and static readings using hand-held meters will continue to be collected at all reaches due to the large number of reaches and few numbers of data loggers available.

Revisions to Stream Fish Protocol (Dodd et al. 2008)

In version 1.0 of the stream fish protocol all reaches were sampled for fish, habitat, and water quality. In August 2008, a start-up review was conducted for the Heartland I&M Network. Several recommendations were made by the review panel regarding aquatic vital signs monitoring (Fancy 2008). The network recognized that the level of monitoring (number and scope of vital signs) described in the vital signs monitoring plan (DeBacker et al. 2005) was too ambitious with current staffing and funding levels. The review panel agreed that the network was operating on a "razor-thin margin" with little opportunity for making adjustments in the event of staff turnover, equipment failures, poor weather, or other events that must be expected with any long-term monitoring program. The review panel concurred with the network's efforts to trim costs and make field efforts more efficient. Several measures to reduce the workload and make the program sustainable were recommended. For aquatic vital signs, the following recommendations were made:

- Do not implement the geomorphic vital signs protocol that was delivered by a contractor and seems to be impractical. Instead, incorporate a few simple geomorphic measures into the aquatic macroinvertebrate and/or fish protocols
- Defer the monitoring of Hellbenders by network staff given the rareness and difficulty of obtaining adequate data and the difficulty in interpreting the monitoring results (very low potential benefit considering the cost and difficulty of monitoring this very rare species)
- Evaluate staffing for the aquatics program, which seems to be stretched too thin and is behind schedule on getting some of the routine reports out. The network might also want to consider cutting back on the sample size or number of measures for some of the aquatics protocols until additional funding or staff can be found.

Based on the HTLN start-up review recommendations, HTLN staff conducted a thorough assessment of alternatives for reaching sustainable operations. DeBacker et al. (2012) described the results of our assessments and recommended specific changes to the revisit design for TAPR and PIPE and some minor field method and analytical adjustments. The report was peer reviewed and was approved for publication by the Heartland Board of Directors and Midwest Region I&M Program Manager on August 17, 2012.

Major modifications to the stream fish protocol (version 1.0, Dodd et al. 2008) documented in this version (2.0) include changes in the revisit design for PIPE and TAPR. These two parks will be placed on a three-year rotational panel (similar to the other seven small stream parks) whereby once every third year, each park will receive the full sampling regime described in this Protocol Narrative and the SOPs. All stream monitoring reaches at PIPE and TAPR (see Table 8) will be sampled for fish community (including Topeka shiners), physical habitat, and water quality. This full sampling regime will coincide with the year in which aquatic invertebrate sampling is completed at the parks. Annual fish monitoring at TAPR and PIPE will continue at a reduced level (abbreviated regime) during the two off-cycle years

Table 8. Reaches to be sampled during full (F) regime every third year and abbreviated (A) regime annually.

Park	Site	Year								
		1	2	3	4	5	6	7	8	9
PIPE	Lower	F	A	A	F	A	A	F	A	A
	Above Falls	F	–	–	F	–	–	F	–	–
TAPR	1 Lower	A	A	F	A	A	F	A	A	F
	1 Middle	A	A	F	A	A	F	A	A	F
	23 Middle	A	A	F	A	A	F	A	A	F
	2 Lower	–	–	F	–	–	F	–	–	F
	4 Middle	–	–	F	–	–	F	–	–	F
	10 Middle	–	–	F	–	–	F	–	–	F
	12 Middle	–	–	F	–	–	F	–	–	F
	17 Upper	–	–	F	–	–	F	–	–	F
	22 Lower	–	–	F	–	–	F	–	–	F
	24 Lower	–	–	F	–	–	F	–	–	F
	34 Lower	–	–	F	–	–	F	–	–	F
	35 Lower	–	–	F	–	–	F	–	–	F
	36 Middle	–	–	F	–	–	F	–	–	F

where sampling will focus on obtaining fish community data in a subset of reaches (see Table 8). Habitat and water quality measurements will not be collected during years of abbreviated sampling.

Additional changes to the data management were made to reflect new guidance from the Inventory and Monitoring Division (IMD) and changes to the data analysis section were made to include trend analysis and ordinations not included in version 1.0 of this protocol. A summary of changes made in this protocol are listed in Table 9.

Table 9. Summary of modifications made to the stream fish protocol, version 1.0 (Dodd et al. 2008) and documented in version 2.0.

Stream Fish Protocol Narrative Section	Change(s) Made and Justification	Author and Date of Changes	References (if appropriate)
Executive Summary	Added this section. Not in previous protocol.	Dodd (Mar 2020)	–
Issues Addressed	Removed mention of Arkansas darter as candidate species. Species removed as candidate by USFWS.	Dodd (Mar 2017)	USFWS endangered species website: https://www.fws.gov/endangered/
Revision of Fish Protocols	Summarized changes to prairie fish protocol that were fully documented in Dodd et al. 2008. Added new revisit design for PIPE and TAPR (Tables 1 & 2) and justification for this change	Dodd (Mar 2017)	Dodd et al. (2008) Fancy (2008) DeBacker et al. (2012)
Spatial Design	Summarized changes in retaining a subset of reaches at PIPE, TAPR and HOME that was fully documented in Dodd et al. (2008)	Dodd (Mar 2017)	Dodd et al. (2008)
Temporal Design	Added text explaining the full and abbreviated sampling design for TAPR and PIPE	Dodd (Mar 2017)	DeBacker et al. (2012)
Data Management	Section updated to reflect changes in IMD policy (QA/QC, data certification, operational review, and IRMA upload) and revision of database structure	Rowell and Dodd (March 2016); DeBacker (Oct 2018); Dodd and Hinsey (Mar 2020)	Frakes et al. (2015) DeVivo (2016) NPS (2016) Frakes and Kingston (2017) Mitchell et al. (2018) Gallo (2018) memo
Analysis and Reporting	Added more information on trend analyses to be used. Included use of concise reports for reporting/updating.	Morrison and Dodd (June 2016)	
Personnel Requirements and Training	Added detail on number of crew members, experience, and training needed to safely and effectively collect data	Dodd (Mar 2017)	Fancy (2008)
Startup Costs and Budget Considerations	Removed table with out-of-date 2007 startup costs.	Dodd (Mar 2017)	–
Protocol Revision	Added information on separate publication of Narrative and SOPs. Incorporated details regarding prairie fish protocol changes documented in Dodd et al. (2008) to Revision History. Added details of stream fish protocol revisions to Revision History. Added IMD policy on protocol revision process.	Dodd (Mar 2017); Dodd (Mar 2020)	Dodd et al. (2008) DeBacker et al. (2012) Mitchell et al. (2018)
Appendices	Replaced park maps with updated maps of sample reaches and water quality sites	Dodd (Mar 2017)	–

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Appendix 1. Map of Sample Reaches at PIPE

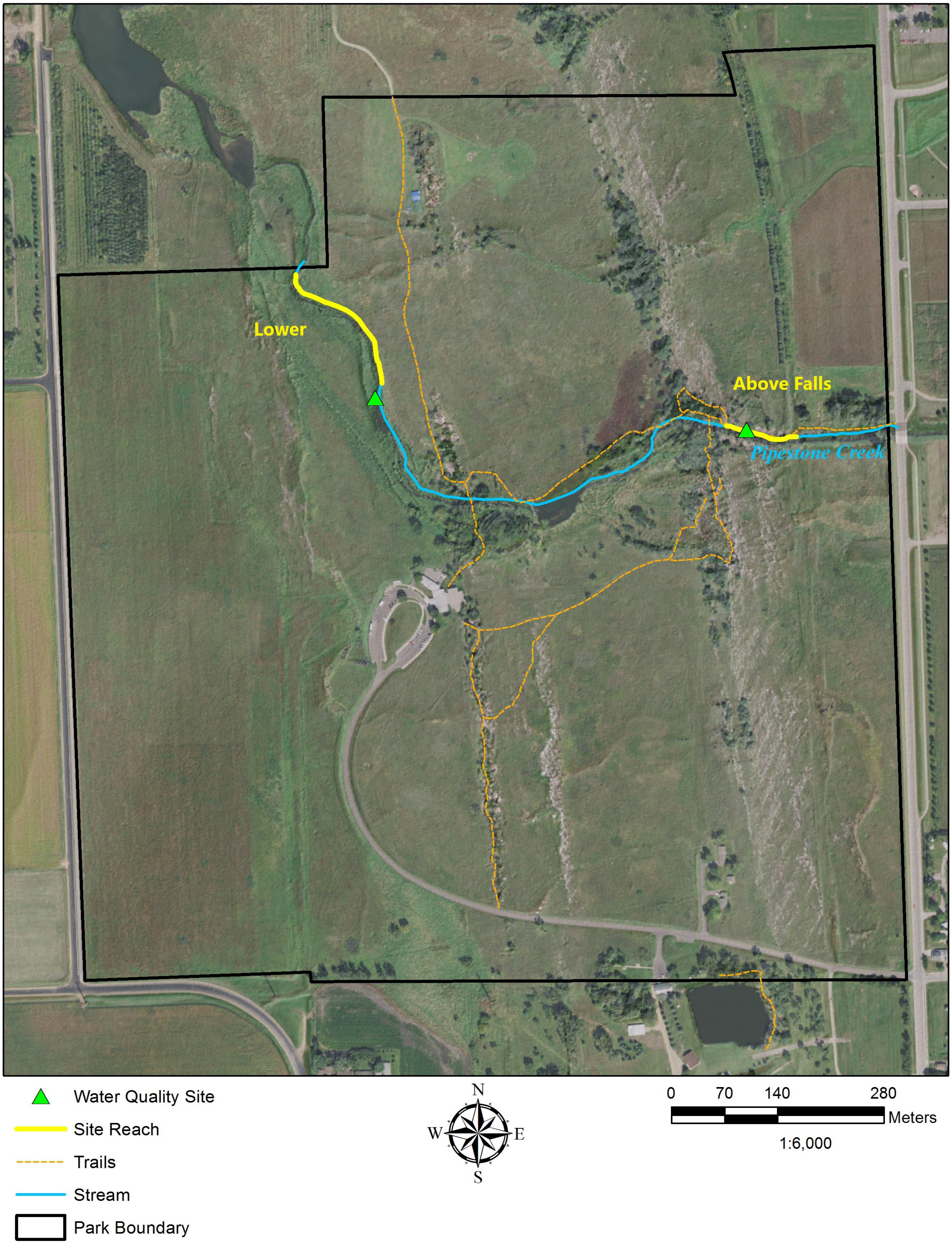

Figure A1. Sample reaches in Pipestone Creek in PIPE.

Appendix 2. Map of Sample Reaches at TAPR

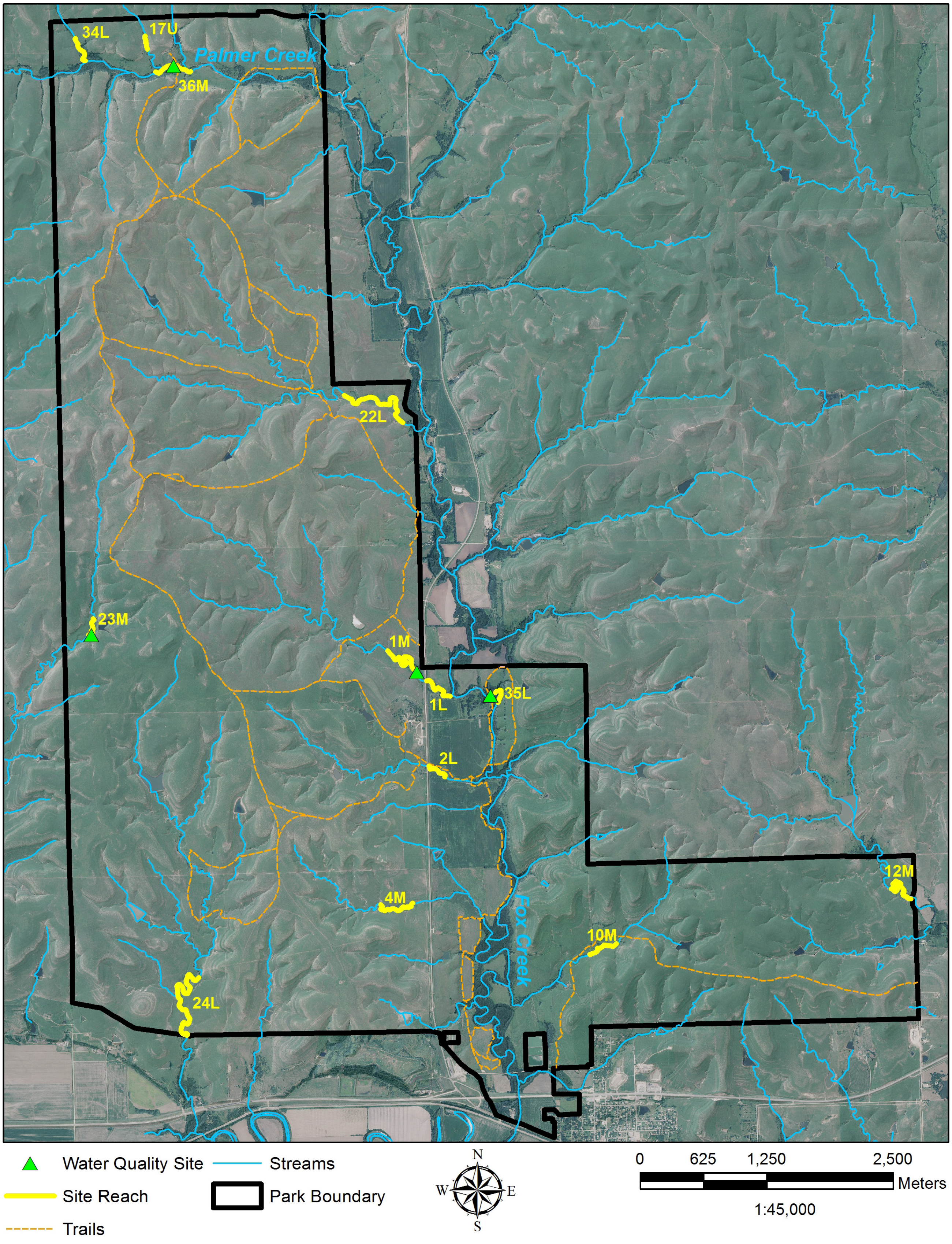

Figure A2. Sample reaches at TAPR. U = upper, M = middle, and L = lower.

Appendix 3. Map of Sample Reach at HOME

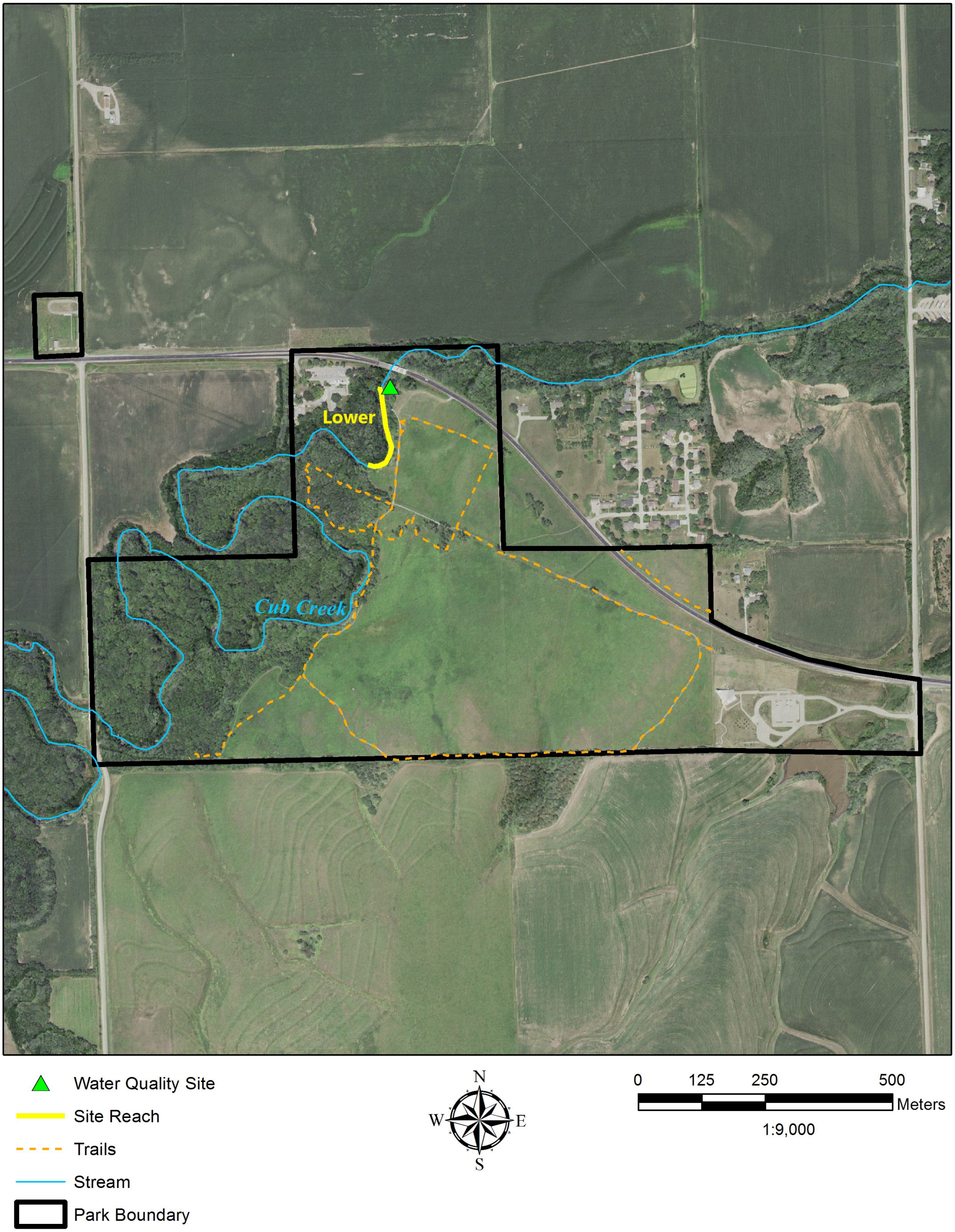

Figure A3. Sample reach on Cub Creek in HOME.

Appendix 4. Map of Sample Reach at EFMO

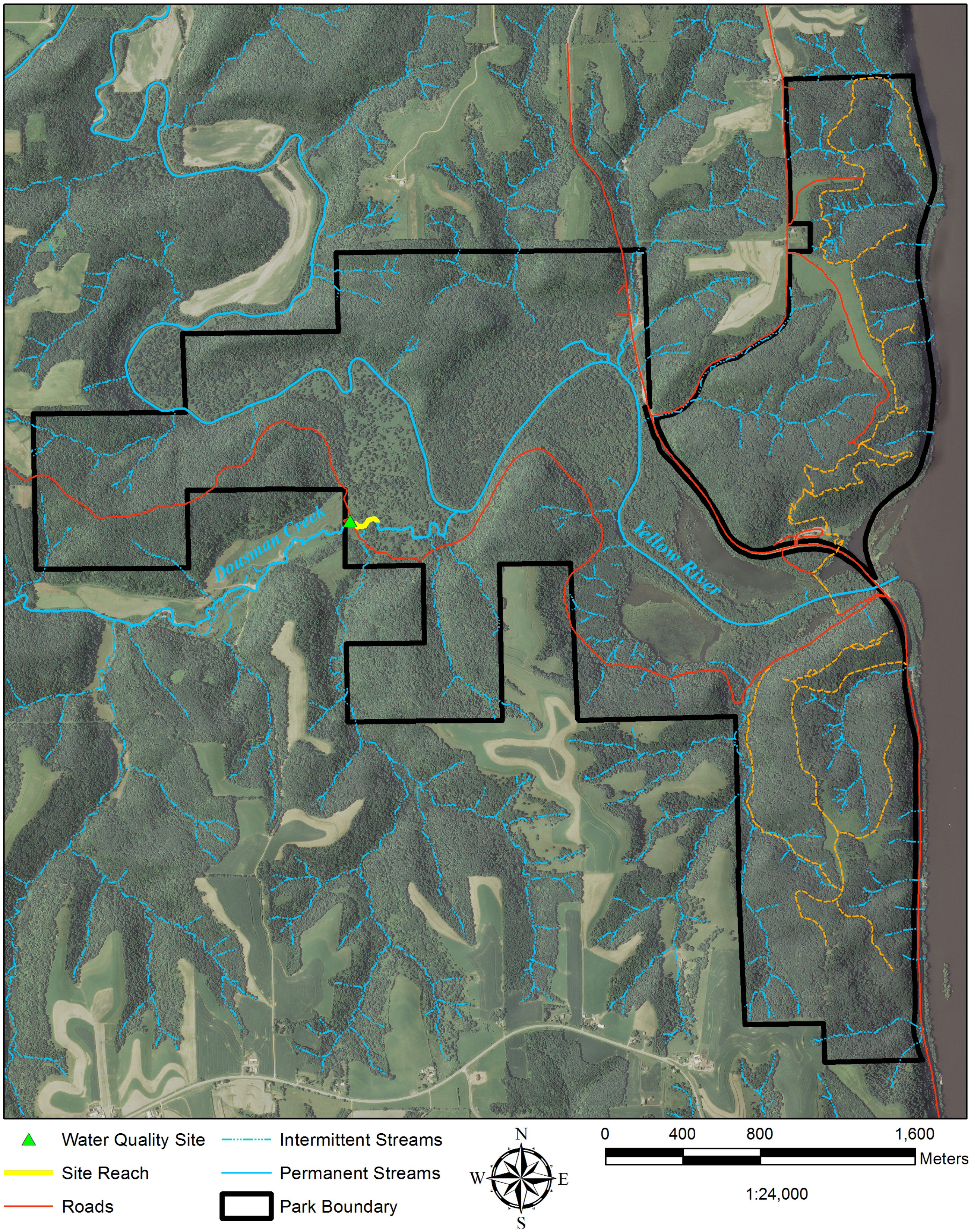

Figure A4. Sample reach on Dousman Creek in EFMO.

Appendix 5. Map of Sample Reaches at GWCA

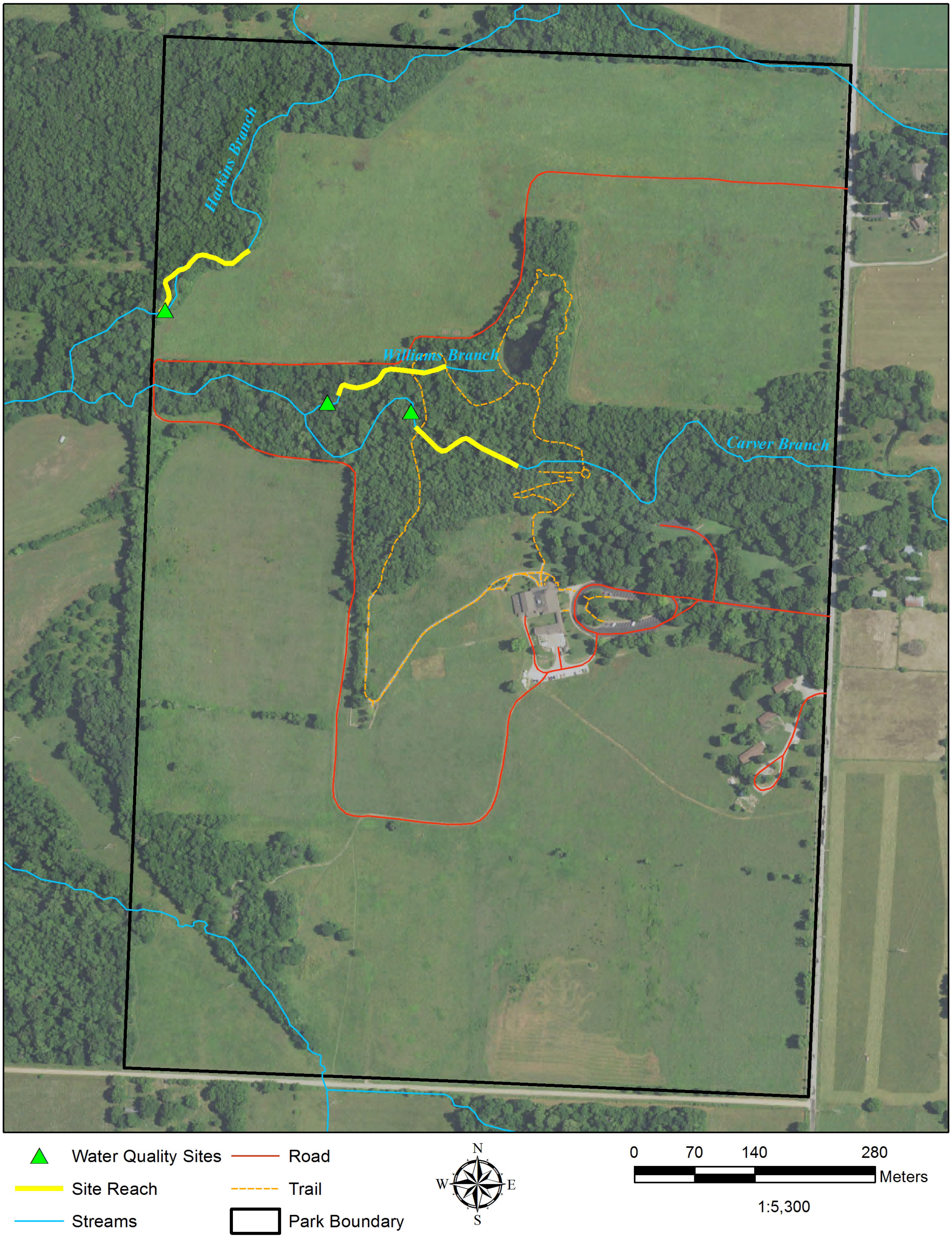

Figure A5. Sample reaches on Carver Creek, Harkins Branch, and Williams Branch in GWCA.

Appendix 6. Map of Sample Reach at HEHO

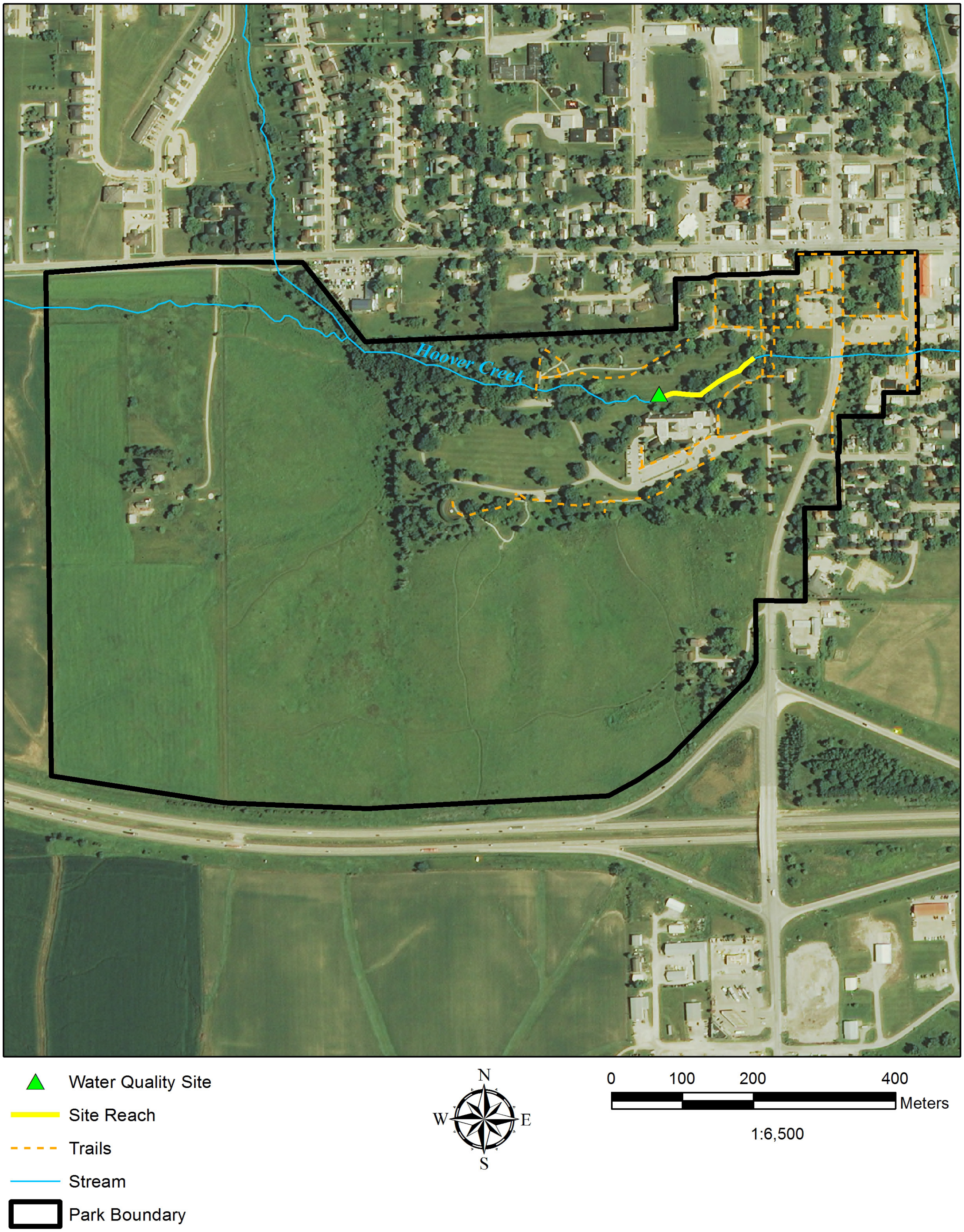

Figure A6. Sample reach on Hoover Creek in HEHO.

Appendix 7. Map of Sample Reaches at HOSP

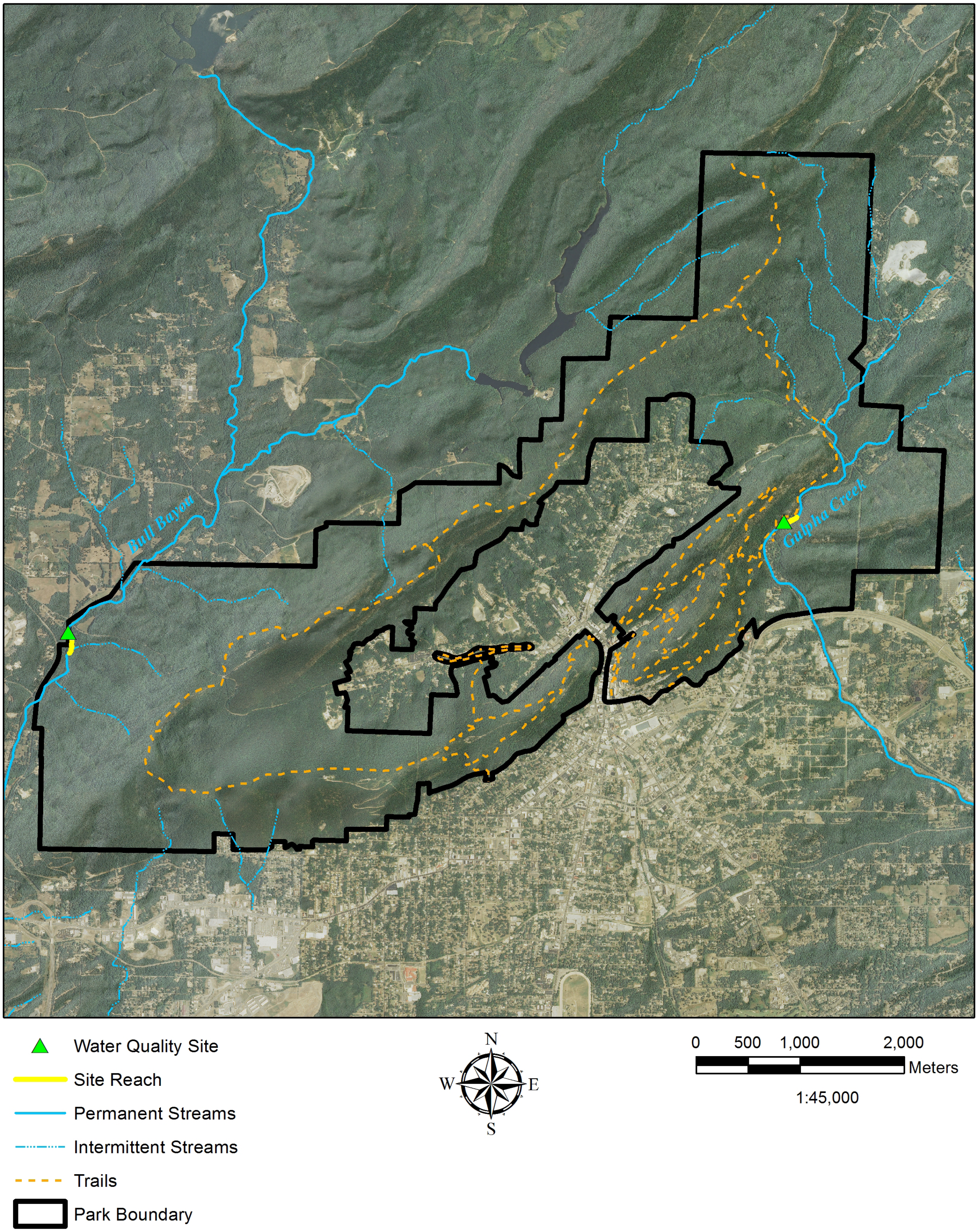

Figure A7. Sample reaches on Bull Bayou and Gulphur Creek in HOSP.

Appendix 8. Map of Sample Reach at PERI

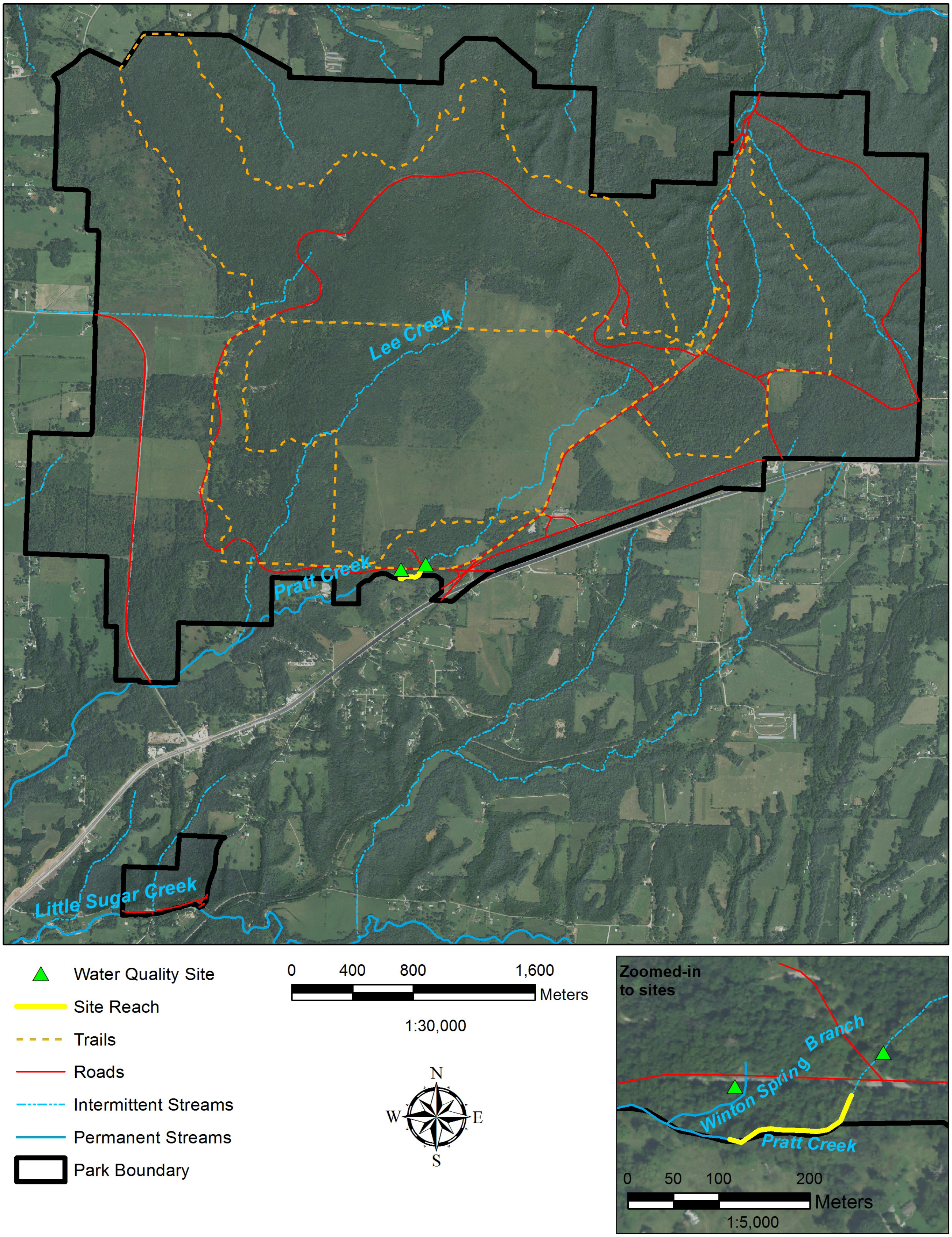

Figure A8. Sample reach on Pratt Creek in PERI.

Appendix 9. Map of Sample Reaches at WICR

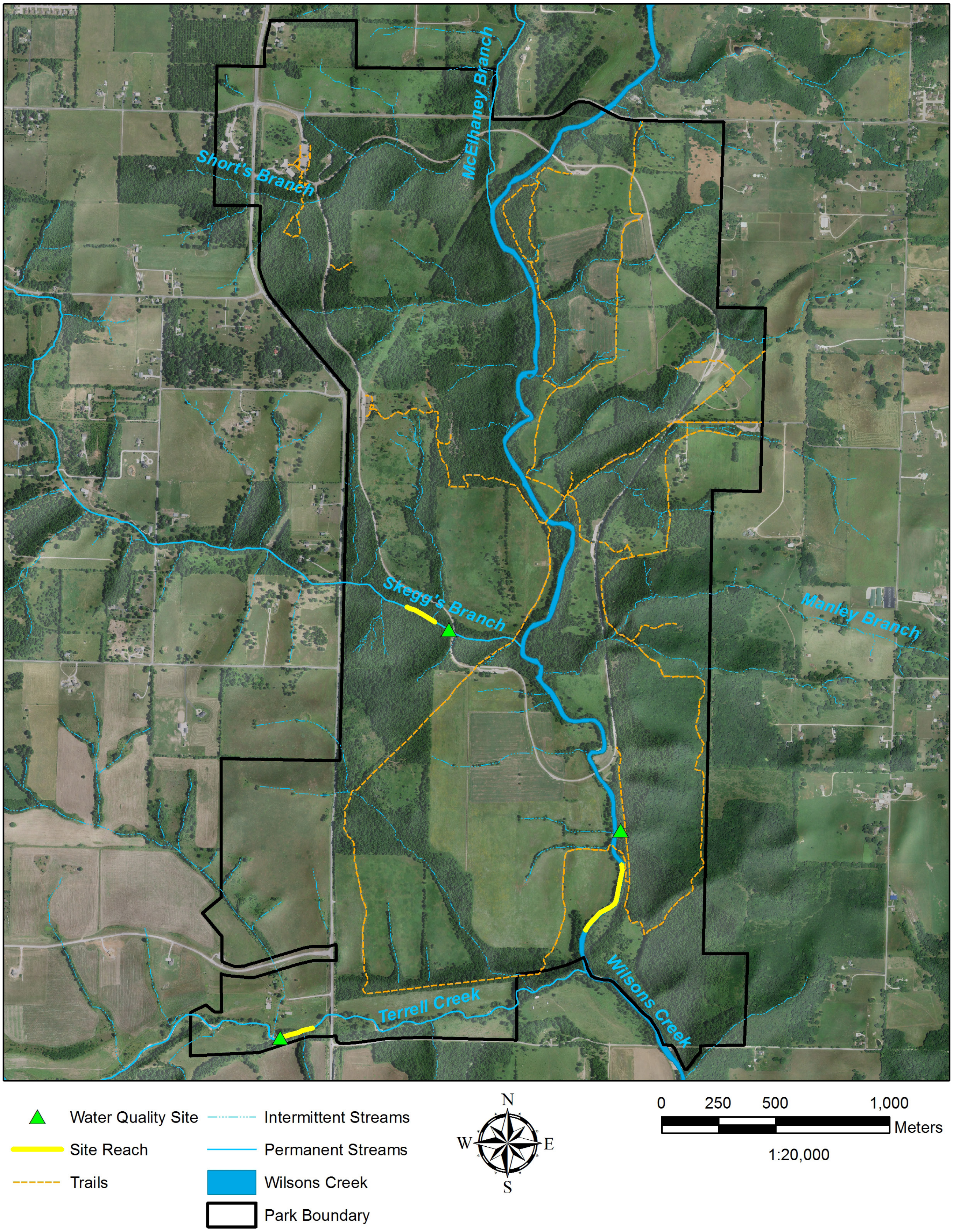

Figure A9. Sample reaches on Terrell Creek, Skegg's Branch, and Wilson's Creek in WICR.

NPS 920/175110, March 2021

National Park Service
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