INFORMAL TRAIL MONITORING IN THE ATIGUN GORGE AREA OF THE ARCTIC NATIONAL WILDLIFE REFUGE

Final Research Report

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Christopher Monz
Associate Professor
Department of Environment and Society
Utah State University
Logan, UT 84321

Jeffrey L. Marion
Unit Leader/Adjunct Professor
Virginia Tech Field Unit
USGS Patuxent Wildlife Research Center
Virginia Tech/FREC (0324)
Blacksburg, VA 24061

Jennifer J. Reed
Visitor Services Supervisor
Arctic National Wildlife Refuge
US Fish and Wildlife Service
Fairbanks, AK 99701

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Abstract

A project to develop, test and implement protocols to detect and monitor the emergence of informal trails in the Atigun Gorge area of the Arctic National Wildlife Refuge (Arctic Refuge) was initiated. Protocols were developed in accord with the current state-of-knowledge on informal trail monitoring and concurrently with a similar study at Denali National Park and Preserve. Field investigations established eleven locations for monitoring proximal to the Dalton Highway in areas of known and likely access to adjacent areas of the Arctic Refuge. Access surveys, line-transect surveys and census mapping approaches were employed as needed at each location. The intention of this project was threefold: 1) to offer considerations for managing visitation-caused trailing impacts, 2) to establish monitoring methods appropriate for Arctic Refuge, and 3) to conduct monitoring in areas of trail management concern before substantial impacts form on the landscape. One location, the Atigun Gorge entrance area, showed some existing impact. Two informal trails and ten nascent trails, defined as *traces*, were present. These observations, combined with previous experimental results on arctic tundra and the likely trend of visitation in the area, suggest that the adoption of an expanded minimum-impact visitor education program encouraging visitor dispersal is needed to avoid the formation of informal trail networks in the near future.

Introduction

The U.S. Fish and Wildlife Service (Service) is one of four Federal land-managing agencies hosting visitation to America's public lands. The Service's mission is to work with others to conserve, protect and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people. The Service helps protect a healthy environment for people, fish and wildlife, and helps Americans conserve and enjoy the outdoors and our living treasures. Though the Service's major responsibilities are for migratory birds, endangered species, certain marine mammals, and freshwater and an anadromous fish, the agency prioritizes recreational opportunities which are wildlife-dependent within its diverse network of national wildlife refuge lands and waters.

Managers of protected natural areas must achieve a careful balance between accommodating sustainable types and amounts of visitation and the protection of natural and cultural resources that may be harmed by visitor use. In high use areas, managers commonly apply a *containment* or concentration strategy to accommodate visitation by providing roads and developments such as parking areas, restroom facilities, and vista sites. These facilities focus visitor traffic on durable surfaces to contain trampling impacts and protect surrounding areas. Similarly, *formal trails* are generally regarded as an essential facility to provide access within moderate to high use portions of protected areas, accommodating recreational opportunities and protecting resources by concentrating visitor traffic on resistant tread surfaces (Marion & Leung 2001).

In low-use areas, where *visual resource management* is a priority, managers commonly promote a *dispersal* strategy to accommodate visitation without formal site developments, facilities, or trails. A common objective is to preserve the area's pristine natural conditions and processes, uninfluenced by human use and impact. The limited occurrence of visitor-created trails and recreation sites may be tolerated in areas where visitor use is transitional from more concentrated to more dispersed, or near popular attraction features, but more commonly these changes in characteristics are actively discouraged. This objective is generally accomplished by asking visitors to disperse their activities along travel routes, and restrict traffic to the most durable natural surfaces available. These are common low impact practices advocated by the national Leave No Trace program (www.LNT.org) to minimize wear in any one location, and increase the probability that the area will retain an undisturbed appearance. Unfortunately, visitor traffic along common travel corridors, on sensitive vegetation or soils, or near popular destinations can result in the creation and proliferation of visitor-created *informal trails* (ITs), sometimes referred to as "social trails."

The emergence, proliferation in number and expansion in length of ITs are perennial management concerns in areas managed for trail-less landscape characteristics, where formal trails are not provided and managers seek to prevent the creation and proliferation of IT networks. Protected area managers who need to make decisions regarding the selection, implementation, and evaluation of actions to address IT impacts often delay decisions that might otherwise preserve natural landscape characteristics due to the difficult management challenges ITs present. Such protected areas are often lightly-managed, sparsely-staffed, and remotely-located, so ready management tools or resources to prevent this kind of incremental erosion of natural characteristics do not abound. Some managers confounded by how to take actions to prevent such impacts may hope the emergent informal trails they observe are caused by

ungulates or other animals, even though casual field observations present obvious, quantifiable differences between human-caused foot traffic impacts and wildlife-caused landscape characteristics. Criteria to aid in distinguishing between human- and wildlife-caused trails are presented later in this report.

Once the emergence and formation of ITs are identified, clear determinations about preventive visitor best practices need to be devised to minimize impacts to natural resources and visitor experiences, including visual resources, collectively expressed as *natural conditions*. Low levels of repetitious traffic in many vegetation types can create ITs, and sometimes topography can focus even very low levels of traffic to an extent that trails or barely distinguishable trails, called traces, appear. Site-specific judgments should holistically consider resource resistance (ability to tolerate trampling) resilience (ability to recover from trampling), use level, distribution of access, and adjacent alternate route-finding opportunities when determining where visitors should be encouraged to contain their trampling to existing sites or trails, or to disperse their activities away from emerging trails or sites to promote their recovery. Communicating to the public the most effective "best practice" guidance in a way that is perceived clearly and objectively, particularly when messages may vary for different contexts, is an additional challenge.

Managers seeking to preserve pristine natural landscape characteristics can benefit from visitor resource impact monitoring programs, which offer an important tool for evaluating the efficacy of alternative educational, regulatory, and site management actions implemented to promote visitor dispersal. Impact monitoring programs and protocols periodically assess resource conditions so that managers can determine the need for action, select effective actions, and evaluate their effectiveness over time. With respect to IT networks, monitoring protocols could be developed to evaluate their spatial distribution, aggregate lineal extent, and tread conditions.

In preparation for long-term visitor use management and *Wilderness* stewardship planning, and response to these concerns and challenges, Service managers at Arctic National Wildlife Refuge (Arctic Refuge) sponsored this research to explore the feasibility of detecting and monitoring the emergence and establishment of ITs. Arctic Refuge, like many other national wildlife refuges in Alaska, is remote and lightly-visited, and yet visitors (individually and cumulatively) contribute inevitable negative impacts to fragile resources. Spanning five distinct ecotypes, straddling the Brooks Range Mountains, and reaching from the Dalton Highway to the Canada border in the northeast corner of Alaska, Arctic Refuge is managed as a 19.6 million acre intact *wilderness* ecosystem. Developments, including structures, roads, and formal trails, do not exist. Bush planes, and the Dalton Highway adjacent to Arctic Refuge's western boundary, are the primary means of visitor access.

This program of research was guided by the following objectives:

1) Investigate alternative methods for monitoring the spatial distribution, aggregate lineal extent, and tread conditions of informal (visitor-created) trails within the Arctic Refuge.

2) In consultation with staff, develop, pilot test, and refine cost-effective and scientifically defensible trail monitoring procedures that are fully integrated with the Arctic Refuge's Geographic Information System.

3) Prepare a technical report that compiles and presents research results and their management implications.

This report presents the protocol development and field testing process, illustrates the types of data produced by their application, and provides guidance for their application and use. The protocols described provide wildland managers with an efficient means to document and monitor IT conditions in settings from pristine to frequently-visited. They were developed and field-tested at Arctic Refuge's Atigun Gorge area, which receives visitors engaged in a wide range of activities, and through collaborations with a similar companion study at Denali National Park and Preserve (Denali NPP) (Marion & Wimpey 2011). The majority of land within both protected areas is managed as trail-less wilderness with the intent to prevent the creation and proliferation of IT networks.

Justification for Monitoring

Sustaining any type of long-term natural resource monitoring program over time can be exceptionally challenging for agencies due to changing personnel, management priorities, and budgets. This section reviews legislative mandates, management policies and guidelines, visitor use capacity, visitor perceptions of recreation resource conditions, and monitoring program capabilities. The purpose of this review is to describe legislative and management intent regarding visitor impact monitoring and its role in balancing visitor use and resource protection objectives. This section is included to assist in justifying implementation of a trail monitoring program and to describe its utility to enlist organizational support for sustaining such a program over time.

Legislative mandates challenge managers to develop and implement management policies, strategies, and actions that permit recreation without compromising ecological and aesthetic integrity. Furthermore, managers are frequently forced to engage in this balancing act under the close scrutiny of the public, competing interest groups, and the courts. Managers can no longer afford a wait-and-see attitude or rely on subjective impressions of deterioration in resource conditions. Professional land management increasingly requires the collection and use of scientifically valid research and monitoring data to support and evaluate efforts to prevent *impacted* and *impaired* resource conditions. Such data should describe the nature and severity of visitor impacts and the relationships between controlling visitor use and biophysical factors. These relationships are complex and not always intuitive. A reliable information base is therefore essential to managers seeking to develop, implement, and gauge the success of visitor and resource management programs.

Although numerous reasons for implementing a visitor impact monitoring program are described in the following sections, the actual value of these programs is entirely dependent upon the staff who manage them. Programs developed with little regard to data quality assurance or operated in isolation from resource protection decision-making will be short-lived. In contrast, programs originating from clear management goals, and providing managers with relevant and reliable information necessary for developing and evaluating resource protection actions, can be of significant value. Only through the development and implementation of professionally managed and scientifically defensible monitoring programs can we hope to provide legitimate answers to the question, "Are we loving our public lands to death?"

Legislative Mandates

While prioritizing achievements to meet the focused Service mission of habitat and species conservation, relatively little guidance exists for national wildlife refuges seeking to manage visitor use aside from three laws which shape the Service's relationship to the public. The three key laws for the Service that are most applicable to visitor use management are: the National Wildlife Refuge Recreation Act of 1962; the National Wildlife Refuge System Administration Act of 1966; and the National Wildlife Refuge System Improvement Act of 1997. For individuals seeking more detail on this topic, these laws have been compiled and explained in a

book titled, "The National Wildlife Refuges: Coordinating a Conservation System through Law," written by Robert L. Fischman (2003).

Though these laws do not provide specific guidance about visitor management, such as determining visitor use capacities or monitoring of recreational impacts, they clearly mandate the provision of high quality public uses and recreational opportunities (especially those associated with wildlife). All uses of a national wildlife refuge over which the Service has jurisdiction must be determined to be appropriate under the Appropriate Refuge Uses Policy (Service Manual 603 FW 1). Generally, specific Service policy and guidance affecting visitor management has been focused around management of commercial uses of national wildlife refuges through its special use permit system and permit stipulations which allow/disallow certain commercial recreational uses of refuges through its special use permit system and permit stipulations. The Service Manual chapter on wildlife-dependent recreation sections 1.6 through 1.14 contains general language that supports the need for monitoring. The Service Manual directing designated Wilderness stewardship also contains limited general guidance about visitor use management or capacity.

Each refuge unit, established for specific wildlife and habitat conservation purposes, and as part of a national network of lands and waters, is managed to fulfill its unique conservation purposes and achieve its goals and objectives as outlined in its Comprehensive Conservation Plan (CCP). CCPs include a review of the appropriateness and compatibility of existing uses and any planned future public uses of refuge lands. In Alaska, CCPs and their subsequent revisions follow guidance found in ANILCA in addition to other Federal laws, primarily the National Wildlife Refuge System Administration Act of 1966, as amended by the National Wildlife Refuge System Improvement Act of 1997, and the National Environmental Policy Act of 1969 (NEPA), as amended. CCPs provide management direction for a 15-year horizon.

Some refuges, if a management need exists, may pursue visitor use-specific management planning within its general conservation planning efforts. Refuges may also prescribe one or more step-down management plans as an objective or an implementation strategy after completing a CCP. Refuges may also address management issues such as visitor use management through a stand-alone step-down plan, outside a CCP process (most often called a Visitor Services Plan across the National Wildlife Refuge System, but referred to as a Visitor Use Management Plan-or VUMP-at Arctic Refuge). The CCP is equivalent to the National Park Service's General Management Plan, whereas visitor services plans may be considered equivalent to a Backcountry Management Plan.

Any visitor use monitoring work should be consistent with management guidelines and goals and objectives identified in the refuge unit's CCP and/or its step-down plans. Arctic Refuge began this trail monitoring research project prior to initiating revision of its CCP, and has since committed to developing a visitor use management in a step-down plan immediately following completion of the Revised CCP, to be called our Visitor Use Management Plan (VUMP). This technical report seeks to support effective stewardship of Arctic Refuge's natural conditions, consistent with guidelines for management of visual resources, recreation and other public uses, public use facilities, and outreach and education, as identified in the Revised CCP. As Arctic

Refuge staff begins its effort to conduct visitor use planning, this report will provide a useful range of ideas applicable to their visitor use management in general.

Several external documents also guide Arctic Refuge's management practices. Relevant external documents include the Wilderness Act of 1964 (PL. 88-577) and the National Environmental Policy Act of 1969 (42 USC 4321 et seq). For example, Congress intended the Wilderness Act to overlay additional protections of the *Wilderness character* of natural resources, processes, and visitor experiences in national wildlife refuge lands that are also designated as Wilderness.

Wilderness, as defined in the Wilderness Act of 1964 (16 USC 1131-1136), is:

> "an area where the earth and its community of life are untrammeled by man . . . which is protected and managed so as to preserve its natural conditions and which generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable. . . ."

The Wilderness Act establishes for national wildlife refuges hosting designated Wilderness a use and preservation management paradox that is tempered by the focused Service mission and clarified through agency-specific policy. Wilderness areas:

> "shall be administered for the use and enjoyment of the American people in such manner as will leave them unimpaired for future use and enjoyment as wilderness and so as to provide for the protection of these areas, the preservation of their wilderness character, and for the gathering and dissemination of information regarding their use and enjoyment as wilderness. . . ."

The National Environmental Policy Act of 1969 (42 USC 4321 *et seq*) directs federal agencies to use all practicable means to "attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences. . . ." Title I of the act requires that federal agencies "monitor, evaluate, and control on a continuing basis their agency's activities so as to protect and enhance the quality of the environment." This amendment also directs agencies to "promote the development and use of indices and monitoring systems to assess environmental conditions and trends, to predict the environmental impact of proposed public and private actions and to determine the effectiveness of programs for protecting and enhancing environmental quality."

Monitoring Program Capabilities

Visitor impact monitoring programs can be of significant value when providing managers with reliable information necessary for establishing and evaluating resource protection policies, strategies, and actions. When implemented with periodic reassessments, these programs produce a database with substantial management benefits (**Error! Reference source not found.**). Data from the first application of impact assessment methods can objectively document the types and extent of visitor impacts. Such work also provides information needed to select appropriate biophysical indicators and formulate realistic standards, as required in many planning and decision-making documents.

Reapplication of impact assessment protocols as part of a monitoring program provides an essential mechanism for periodically evaluating resource conditions in relation to standards. Visitor impact monitoring programs provide an objective record of impacts, even though individual managers come and go. A monitoring program can identify and evaluate trends when data are compared between present and past assessments. If foreseeable threats are identified, monitoring may detect the appearance of impacts or deteriorating conditions before severe or irreversible changes occur, allowing time to implement corrective actions. Analysis of monitoring data can reveal insights into relationships with causal or non-causal yet influential factors. For example, the trampling and loss of vegetation or soils may be greatly reduced by shifting traffic to more resistant and resilient vegetation types or better trail alignments, instead of limiting use. Following the implementation of corrective actions, monitoring programs can evaluate their efficacy.

- Identify and quantify site-specific resource impacts.
- Summarize impacts by environmental or use-related factors to evaluate relationships.
- Aid in setting and monitoring resource conditions standards of quality.
- Evaluate deterioration to suggest potential causes and effective management actions.
- Evaluate the effectiveness of resource protection measures.
- Identify and assign priorities to maintenance needs.

Figure 1. Capabilities of visitor impact monitoring programs.

Visitor Perceptions of Resource Conditions

Visitors to wildland environments are aware of resource conditions along trails and at recreation sites, just as are managers (Lucas 1979, Marion & Lime 1986, Vaske *et al.* 1982). Seeing trails and recreation sites, particularly those in degraded condition, reminds visitors that others have preceded them. Visitor perceptions of an area and its naturalness are strongly influenced by encountering or seeing trail or recreation site impacts. Visitors are sensitive to overt effects of other visitors (such as the occurrence of litter or malicious damage to natural resources) and to visually obtrusive examples of impacts such as tree root exposure, tree damage/felling, and soil erosion.

Understanding and minimizing the ecological disturbance caused by off-trail hiking is important to maintaining both the environmental and social aspects of the recreation experience. Research demonstrates that the quality of a visitor's experience is likely to decrease if degradation to a trail is present (Lynn & Brown 2003). For example, a pilot survey of visitors to Arctic Refuge (Christensen & Christensen 2009) provides some general indicators of visitor perceptions regarding resource conditions (Note: In this survey, respondents understood the term "Wilderness" to encompass all Arctic Refuge wildland, whether designated Wilderness or Minimal Management wilderness). According to this survey, the greatest positive influence on visits came from experiencing "Wilderness" (92%), "A Sense of Vastness" (92%), "Remoteness and Isolation" (89%), "A Sense of Adventure" (84%), and "Natural Conditions" (84%). The Arctic Refuge purposes most frequently rated as "Very Important" were "Wildlife" (97%), "Wilderness" (96%), "A bequest to future generations" (89%), "Remoteness and isolation"

(89%), and "A place where natural processes continue"(86%). Respondents encountered an average of two other groups on their trip, saw or heard four airplanes, and saw an average of one site with evidence of previous visitor use. Survey results will be used by Arctic Refuge staff, along with input from public scoping during the recent long range planning effort, to refine the survey instrument, and to conduct further surveys of visitor perceptions of resource conditions. This information, in turn, will be part of the information managers use to determine *desired condition* thresholds for long-term visitor use management.

Visitor Use Management and Capacity Decision-Making

Visitor use and impact management decisions at Arctic Refuge will be addressed through a public planning process separate from its Revised Comprehensive Conservation Plan, (Note: at the time of this report's completion, staff are seeking completion of the Revised Plan—signified through a Record of Decision submitted by the Service's Regional Director). Managers have elevated the priority for initiating the Visitor Use Management Plan to begin immediately upon implementation of the Revised Plan. As part of these planning efforts, staff will consider levels of use, timing and distribution of use, and activities and behaviors of visitors, to evaluate a range of management actions appropriate to sustain, and restore where necessary, desired resource conditions and visitor experiences that preserve *wilderness characteristics* and are consistent with the values for which the area was established.

A monograph entitled "Capacity Reconsidered," and authored by the Capacity Work Group (Doug Whittaker, Bo Shelby, Robert Manning, and Glenn Haas) asserts that management prescriptions, comprised of multiple management actions meant to achieve desired conditions, must include 1) management goals and objectives for uses/values/desired opportunities, 2) defined desired conditions, 3) standards that quantitatively define levels for indicators, 4) a planned management program with actions that violate standards, and 5) budget and personnel/resources dedicated to implementing management actions, if they are to be effective. It is the skill of blending these components of effective management, with the right amounts and kinds of each component, which makes protected land management an art, refined through decision-making and public input, and guided by informed evaluation of the area to be stewarded. Land managers are not afforded the ease of clear "right" or "wrong" answers for how to best preserve desired conditions. However, they do face the likely compromises that are necessary to address problems threatening desired conditions so they can be maintained (e.g.: Arctic Refuge may want to offer optimal freedom from regulation, solitude from other visitors, and pristine wilderness characteristics for its visitors to experience, but not all three may be simultaneously possible if visitor use levels currently sustained at Atigun Gorge continue.

Managers of protected natural areas increasingly employ planning and decision-making frameworks such as the National Park Service's Visitor Experience and Resource Protection (VERP) framework for making formal evaluations of the acceptability of visitor impacts and for establishing carrying capacity limits on visitation (NPS 1997, NPS 2006b). The Denali NPP final research report on informal trails previously mentioned (Marion & Wimpey 2011), presents this framework and its application to trail monitoring in Alaska's lightly-visited public lands. Under these newer frameworks, numerical standards are set for individual biophysical or social condition indicators. Managers must evaluate the types and extents of resource impacts

associated with recreational activities, and determine to what extent they are unacceptable and constitute impairment, *relative to visitor use levels*. The limits set through the selection of quantitative indicator standards define the critical boundary between acceptable and unacceptable change in resource or social conditions, and against which future conditions can be compared through periodic monitoring. Such frameworks are adaptive management processes wherein periodic monitoring is conducted to compare actual conditions to quantitatively defined, pre-determined standards of quality. If standards are exceeded, an evaluation is conducted to identify those factors that managers can effectively manipulate to improve conditions for the indicators with sub-standard (unacceptable) conditions. Corrective actions are then implemented with subsequent monitoring to evaluate their efficacy in correcting sub-standard conditions.

Literature Review

Arctic Refuge visitors participate in a diverse array of recreation activities, including hunting, fishing, wildlife observation, photography, camping, backpacking, river floating, and mountaineering. Such activities contribute to an equally diverse array of effects on protected area resources, including vegetation, soils, water, and wildlife. The term *impact* is commonly used to denote any undesirable visitor-related change in these resources.

Trail Impacts

Resource impacts associated with trampling on trails include an array of direct and indirect effects such as fragmentation of habitats, and degradation of vegetation and soil (**Error! Reference source not found.1**). Even light traffic can remove protective layers of vegetation cover and organic litter (Cole 2004, Leung & Marion 1996). Trampling disturbance can alter the appearance and composition of trailside vegetation by reducing vegetation height and favoring trampling resistant species. The loss of tree and shrub cover can increase sunlight exposure, which promotes further changes in composition by favoring shade-intolerant plant species (Hammitt & Cole 1998, Leung & Marion 2000).

When a trail is constructed or created from visitor use, the surface vegetation and organic litter are lost, exposing underlying mineral soil that is shaped and compacted into a durable tread to support visitor traffic. However, exposure of soil on natural surfaced trails can lead to several resource impacts, including soil compaction, muddiness, erosion, and trail widening (Hammitt & Cole 1998, Leung & Marion 1996, Tyser & Worley 1992). The compaction of soils decreases soil pore space and water infiltration, which in turn increases muddiness, water runoff and soil erosion. The erosion of soils along trails exposes rocks and plant roots, creating a rutted, uneven tread surface. Eroded soils may smother vegetation or find their way into water bodies, increasing water turbidity and sedimentation impacts to aquatic organisms (Fritz 1993). Visitors seeking to circumvent muddy or badly eroded sections contribute to tread widening and creation of parallel secondary treads, which expand vegetation loss and the aggregate area of trampling disturbance (Marion 1994, Liddle & Greig-Smith 1975).

Table 1. Direct and indirect effects of recreational trampling on soils and vegetation.

Effects	Vegetation	Soil
Direct	Reduced height/vigor Loss of ground vegetation, shrubs and trees Introduction of non-native vegetation	Loss of organic litter Soil exposure and compaction Soil erosion
Indirect	Altered composition – shift to trampling resistant or non-native species Altered microclimate	Reduced soil pore space and moisture, increased soil temperature Increased water runoff Reduced soil fauna

A fairly small number of studies have examined foot trail impacts to arctic vegetation. Reid and Schreiner (1985) conducted experimental human trampling research at Denali NPP within three vegetation types to examine impact and recovery rates. A plant community's ability to tolerate recreational traffic with minimal impact is determined by its initial resistance to the effects of trampling disturbance, and its resilience, or ability to recover following disturbance. A tundra community dominated by *Dryas octopetala* was found to be the most trampling resistant and resilient community, with the boreal forest community the least resistant and resilient. A community described as shrub tundra was found to have an intermediate capacity for resistance and resilience. However, even in the resistant tundra plant community, a 25% reduction in plant cover was achieved with only two passes one week followed by four passes the next week, repeated over the course of the summer (40 passes/season). Total plant cover in the boreal forest was reduced by 75% under that same treatment level. The recovery rate of the graminoid alpine tundra plants (grasses and sedges) was more rapid than the woody vegetation in either the boreal forest or shrub tundra.

A more recent and comprehensive experimental human trampling study of Alaskan arctic tundra was conducted by Monz (2002). This study investigated trampling within dryas and tussock tundra communities, both of which lost approximately 50% vegetative cover after 200 passes. At 500 passes the majority of cover was lost, with regeneration to approximately 80% vegetative cover after four years. Indices of resistance and resilience found the dryas tundra to be slightly more trampling resistant than the tussock tundra; both communities have substantial resilience, particularly the tussock community. Findings suggest that if the number of passes is kept below about 200/year that regeneration of plant cover can occur in one or two growing seasons in the absence of further trampling.

The creation and use of trails can also directly degrade and fragment wildlife habitats, and the presence of trail users may disrupt essential wildlife activities such as feeding, reproduction and the raising of young (Knight & Cole 1995). For example, Miller and others (1998) found decreased presence of nesting birds near trails in grassland ecosystems. Trails can alter hydrology by intercepting and channeling surface water (Sutherland *et al.* 2001), and fragment the landscape with potential barriers to flora and some small fauna (Leung *et al.* 2002, Leung & Louie 2008). Finally, visitors and livestock can also introduce and transport non-native plant species along trails, some of which may out-compete undisturbed native vegetation and migrate away from trails (Benninger-Truax *et al.* 1992, Adkison & Jackson 1996, Bhuju & Ohsawa 1998, Potito & Beatty 2005, Hill & Pickering 2006)

Most trail-related resource impacts are limited to a linear corridor of disturbance, though impacts like altered surface water flow, invasive plants, and wildlife disturbance, can extend considerably further into natural landscapes (Kasworm & Monley 1990, Tyser & Worley 1992). Even localized disturbance within trail corridors can harm rare or endangered species or damage sensitive plant communities, particularly in environments with slow recovery rates.

Grulke (1987) monitored disturbance and recovery of foot trails in well-drained upland tundra in the Arctic Refuge. Tundra was highly susceptible to damage, but began recovering when trampling ceased, due to the resilience shown by some dwarf shrubs and mosses. An important

factor in the ability to recover was maintenance of an unbroken soil organic layer, which harbors most plant roots.

Studies of effects of off-road vehicles (ORV), sometimes referred to as all-terrain vehicles (ATV), on tundra provide useful insights. Though use of ORVs of is generally prohibited in Alaska's national wildlife refuges [43 CFR 36.11(g)], they are allowed with some exceptions. Abele (1976) and Abele *et al.* (1984) conducted some early studies examining ORV impacts to Alaskan tundra, finding that moist tundra resists disturbance better than wet tundra, but it is less resilient once disturbed. Furthermore, that above-ground tundra disturbance can recover in less than 10 years, while disturbance of substrates and root systems lengthens recovery. This is particularly true when the removal of substrates causes permafrost melting and subsidence.

Also studying ORV impacts, Wooding and Sparrow (1979) note that the thick tundra normally insulates substrates from changes in temperature. When the tundra mat is removed by recreational traffic the underlying soils absorbs greater radiation, warms, and thaws faster and deeper during the summer months, often developing a soggy quagmire that subsequent traffic seeks to avoid. Happe *et al.* (1998) found considerable variability in ATV impacts between vegetation types in Wrangle-St. Elias National Park and Preserve, Alaska. Most highly impacted were the wet and mesic herbaceous and low shrub communities on permafrost soils. Open forests with well-drained soils had greater resistance, and the fewest impacts occurred in Dryas and tall willow communities on coarse well-drained cobble, gravel and sand substrates.

Disturbance and recovery from winter vehicle traffic has been monitored on the Arctic Refuge coastal plain for 25 years (Jorgenson et al. 2010). Initial impacts are different than those from summer traffic because the soil is frozen, but the amount of recovery is determined by the same factors cited in the above literature.

Informal Trail Impacts

Protected natural areas offer a range of access opportunities and associated visitor experiences. Understanding and minimizing the ecological disturbance caused by dispersed hiking is important to maintaining both the environmental and social aspects of the recreation experience. Where managers offer formal trail networks but do not provide visitors the access and experiences they desire, visitors frequently venture "off-trail" to reach locations not accessible by formal trails. For those managers seeking to offer a high-quality trail-less setting, understanding and minimizing the potential ecological disturbance that can be caused by this activity is important for its perpetuation. In areas that lack formal trails, managers often encourage visitors to disperse their activity to avoid development of trails. However, even relatively low levels of traffic can wear down vegetation and organic litter to create visible IT networks (Weaver & Dale 1978, Thurston & Reader 2001).

The establishment of ITs is commonplace in protected areas, especially areas moderate to high visitation. As previously noted, their proliferation in number and expansion in length over time are perennial management concerns because their presence can detract from an area's overall management goals to preserve natural conditions and they can cause greater cumulative

degradation than formal trails. Because ITs are not professionally designed, constructed or maintained, they can contribute substantially greater impacts to protected area resources than formal trails (Wimpey & Marion 2011a, 2011b). Many of these impacts are related to their poor design, including alignments parallel to slopes or along shorelines, multiple "duplicative" trails accessing the same destinations, routes through fragile vegetation, soils, or sensitive wildlife habitats, and disturbance to rare flora, fauna, or archaeological sites. These design attributes also make ITs far more susceptible to tread impacts, including expansion in width, soil erosion, and muddiness.

Research demonstrates that the quality of a visitor's experience is likely to decrease if degradation to a trail is present (Lynn & Brown 2003), and areas previously untrampled by human footprints can become severely degraded when repeated visitation results in the creation of ITs. A study by Thurston and Reader (2001) found an 81% mean loss of vegetation density in the center zone of new ITs, and a 71% decline in the species present. Mean soil exposure also increased by 23% in these areas.

IT proliferation is common in high visitation settings and in some protected areas is responsible for extensive areas of impact. A study in Mount Rainier National Park on the impacts of IT use identified 913 degraded sites and attributed 89% of them to the presence of ITs (Rochefort & Gibbons 1992). Other studies show that certain landscapes and visitor motivations might make some areas more susceptible to IT proliferation. In areas such as open moorland in the UK, ITs and consequent degradation of the landscape are widely visible (Pearce-Higgins & Yalden 1997). Other areas appear to be more prone to off-trail hiking because most visitors who wander off the official trail are taking a shorter route to a site of interest (Keirle & Stephens 2004). Conversely, ITs are less common in areas that have more dense vegetation or topographical obstructions that impede visitor access (Lehvavirta 1999). In areas where off-trail hiking is activity discouraged, such activity is viewed as a form of depreciative behavior and causes hundreds of thousands of dollars in damage each year (Christensen & Clark 1983). In an effort to reduce IT degradation, educational and site management techniques area available for managers to deter off-trail travel (Park *et al.* 2008).

Trail Management

For protected areas where managers offer trail hiking opportunities, studies show that formal trails with proper trail design and construction principles can substantially reduce adverse impacts to natural resources and the need for trail maintenance (Leung & Marion 1996, Olive & Marion 2009). The source of many forms of degradation along formal trails can be related to poor design attributes such as steep grades, alignments close to the fall line (parallel to landform aspect), or to locations on perennially wet soils. In some instances, such formal trails were originally created by visitors or individuals who lacked trail design expertise, or were directed by objectives in conflict with resource protection goals (Marion & Leung 2004). Even well-designed trails require periodic maintenance and are susceptible to the several forms of degradation when subjected to high use or to high-impact behaviors or types of use (e.g., horse riding and motorized uses) (Aust *et al.* 2004). Because trail management can be challenging to sustain under conditions of declining and limited agency budgets, management decisions which avoid and minimize resource impacts and the need for maintenance are all the more urgent.

ITs are often indistinguishable from formal trails, except for the lack of formal trail blazes or markings. Once created, managers have found it difficult to deter their use and even when successful, their recovery requires long periods of time (Grabherr 1982, Boucher *et al.* 1991, Roovers *et al.* 2005). Restoration work can hasten recovery but is expensive and can require archeological assessment and compliance work. ITs are particularly problematic because they become more visually obvious as they form, acting as a "releasor cue" that draws even more visitors off formal trails (Roggenbuck 1992), or conversely, as a magnet drawing dispersed travelers toward the ITs.

IT proliferation and resource impact is a problem across all types of protected natural areas as shown by research and monitoring studies conducted around the globe (Grabherr 1982, Cole 1990, Manning *et al.* 2006, Wimpey & Marion 2011a, 2011b). Previous research has investigated the deterrence of off-trail hiking through educational messages and site management (Johnson *et al.* 1987, Park *et al.* 2008). However, few studies have extensively mapped or investigated the resource impacts of IT networks within protected natural areas (Cole *et al.* 1997, Leung *et al.* 2002, 2011, Wimpey & Marion 2011a), although several have collected IT counts in conjunction with campsite, recreation site, or formal trail inventories (Marion 1994, Dixon *et al.* 2004, Wimpey & Marion 2011b, Wood *et al.* 2006). Very little work has been done to date on the efficacy of deterrence of IT formation through dispersed trail-less hiking educational messaging.

Indicators and Selection Criteria

Indicators are measurable physical, ecological, or social variables used to track trends in conditions caused by human activity so that progress toward goals and desired conditions can be assessed. An indicator is any setting element that changes in response to a process or activity of interest (Merigliano 1990). An indicator's condition provides a gauge of how recreation has changed a setting. Comparison of an indicator's condition to management objectives or indicator standards reveals the acceptability of any resource changes. Indicators provide a means for restricting information collection and analysis to the most essential elements needed to answer management questions. Examples of questions related to trails include:

Are visitors experiencing an environment where the evidence of human activity is substantially unnoticeable?

Are trail numbers and conditions acceptable given each management zone's objectives and desired conditions?

Are visitor and trail management practices effective in minimizing the establishment of ITs or degradation in formal and ITs?

Before a monitoring program can be developed, appropriate resource indicators must be selected. A single, direct measurement of a trail's condition is inappropriate because the overall condition is an aggregate of many components. Typically, then, monitoring evaluates various soil, vegetation, or aesthetic elements of a trail that serve as indicators of that facility's condition. Cole (1989), Marion (1991) and Merigliano (1990) review criteria for the selection of indicators

(**Error! Reference source not found.2**), which are summarized here. Management information needs, reflected by the management questions such as the examples above, guide the initial selection of indicators.

Preferred indicators should reflect attributes that have ecological and/or aesthetic significance for management decision-making. Indicator measures should primarily reflect changes caused by the recreational activity of interest. For example, measures of soil loss related to trail construction would be inappropriate. Indicators should be measurable, preferably at an interval or ratio scale where the distances between numeric values are meaningful, i.e. a 36-inch wide trail is twice the width of an 18-inch wide trail. In comparison, a categorical condition class "ratings" system based on subjective assessments rather than quantitative measures provides data at an ordinal scale, which can limit subsequent analyses and statistical testing.

Table 2. Criteria for selecting indicators of resource condition.

Criteria	Rationale
Quantitative	Can the indicator be measured?
Relevant	Does the indicator change as a result of the process or activity of interest?
Efficient	Can the measurements be taken by available personnel within existing time and funding constraints?
Reliable	How precise are the measurements? Will different individuals obtain similar data of the same indicator?
Responsive	Will management actions affect the indicator?
Sensitive	Does the indicator act as an early warning, alerting you to deteriorating conditions before unacceptable change occurs?
Integrative	Does the indicator reflect only its condition or is its condition related to that of other, perhaps less feasibly measured, elements?
Significant	Does the indicator reveal relevant environmental or social conditions?
Accurate	Will the measurements be close to the indicator's true condition?
Understandable	Is the indicator understandable to non-professionals?
Low Impact	Can the indicator be measured with minimal impact to the resource or the visitor's experience?

Adapted from Cole (1989), Marion (1991), Merigliano (1990), O'Connor & Dewling (1986).

Potential indicators of resource condition are numerous and there is great variation in our ability to measure them with *accuracy*, *precision*, and *efficiency*. All assessments are approximations of an indicator's true value; a measurement method is *accurate* if it closely approximates the true value. *Efficiency* refers to the time, expertise, and equipment needed to measure the indicator's condition. Unfortunately, efficient methods often yield inconsistent results when applied by different individuals. A measurement method is *precise* if it consistently approximates a common value when applied independently by many individuals (i.e., repeatability). Accurate measurements correctly describe how much change has occurred; precise measurements permit

objective comparisons of change over time (Cole 1989, Marion 1991). Indicator assessment methods should also be considered when selecting indicators. When choosing a method managers must balance accuracy and precision, for each places constraints upon efficiency and cost-effectiveness. For example, recreation site condition assessments range from highly efficient but subjective evaluations (e.g. photographs or condition class ratings), to rapid assessments (ratings based on numeric categories of damaged trees), to time-consuming research-level measurements (quadrat-based vegetation loss assessments). Regardless of the method selected, comprehensive procedural manuals, staff training, and program supervision stressing quality control can improve both accuracy and precision. However, poorly managed monitoring efforts can result in measurement error that confounds data interpretation or even exceeds the magnitude of impact caused by recreational activities.

Preferred Indicators

From these indicator criteria and knowledge of how recreation affects soil, vegetation, and aesthetics, managers select preferred indicators. **Error! Reference source not found.**includes a listing of commonly employed indicators for assessing resource conditions on trails using measurement-based approaches. Generally a small number of indicators are selected for use in decision-making frameworks. However, that does not preclude monitoring of additional resource condition indicators or from also assessing various inventory indicators. Travel time to the sampling locations is often the most substantial portion of the time budget so assessing a few additional indicators can be negligible. A final consideration is the measurement units employed for reporting results and/or setting standards. Measurement-based approaches permit the most flexibility in this respect.

Table 3. Potential indicators of trail conditions and measurement units.

Trail Indicators	Measurement Units
Informal Trails	Mean width, length/unit area, #/unit area, % of formal trail length, #/unit length along formal trails, aggregate length or area of disturbance, habitat fragmentation indicators.
Tread Width	Max. value, value/unit length, running avg./unit length
Maximum Incision	Max. value, value/unit length, running avg./unit length
Cross Sectional Area	Max. value, value/unit length, running avg./unit length
Muddiness	Max. % of tread width, avg. %/unit length, running avg. %/unit length

Trail condition indicators frequently vary by trail type. For example, trail soil loss is most prevalent for higher use formal trails but can also be a problem on some ITs that are poorly aligned or heavily used. For formal trails, preferred indicators commonly include trail widening, soil loss, and muddiness (Cole, 1991; Marion & Leung, 2001; Olive & Marion, 2009). For ITs,

the total lineal extent, aggregate area of disturbance, trail width, and landscape fragmentation are possible indicators (Leung, 2008; Marion *et al*., 2006).

Depending on the assessment protocols employed, managers must also consider measurement units and the unit for which standards are applied. For example soil loss can be assessed at sample points by measuring maximum incision or cross sectional area, with standards specifying maximum allowable values (Cole, 1983; Marion *et al*., 2006). Standards could also be expressed as a value per unit length or as a running average per unit length. Alternatively, if soil loss was evaluated with the problem assessment method, the standard could be set at the level of soil loss established as unacceptable and field staff would only assess soil loss occurrences at or above this level. Alternate standard measures include a length per unit area, percent of trail length, or length per unit length along a subset of trails.

In summary, managers must consider and integrate a diverse array of issues and criteria in selecting indicators for monitoring impacts on trails. Indicators will rarely score high on all criteria requiring good judgment as well as area-specific field trials and direct experience. Indicators that score high on some criteria but low on others may be retained in some instances or omitted in others. Tradeoffs are also required, such as a necessary reduction in accuracy so that precision and efficiency may be increased.

Trail Impact Assessment Survey Methods

This section considers assessment methods for trail surveys that could be applied to either formal or ITs. The trail information collected can be used to inform the public about trail resources, justify staffing and funding, evaluate the acceptability of existing resource conditions, analyze relationships between trail impacts and contributing factors, identify and select appropriate management actions, and evaluate changes in trail conditions and the effectiveness of implemented actions. A variety of efficient methods for evaluating trails and their resource conditions have been developed and described in the literature, as reviewed and compared by Cole (1983), Leung and Marion (2000), and Marion *et al*. (2006). Multiple trail survey protocols can also be integrated in a combined survey (Bayfield & Lloyd 1973, Olive & Marion 2009).

At the most basic level, trails can be *inventoried and mapped* with the use of Global Positioning System (GPS) devices, using either recreational grade (about 3-8m accuracy), or survey grade (<3m accuracy with post-processing) units. Such inventory/mapping surveys provide data that are input to Geographic Information System (GIS) software to provide maps of trail networks and for further analysis of trail impact attributes (Wolper *et al*. 1994, Wing & Shelby 1999). Increasing availability of high-resolution spatial data, such as LIDAR, may enable accurate trail inventory and mapping by trail feature extraction from spatial data in a GIS environment instead of field surveys (Kincey & Challis 2010). Aggregate lineal extent, area of disturbance, and landscape fragmentation indices are some examples of IT impact indicators that GPS/GIS-based trail mapping can provide. Inventory information (type of use, segment lengths, hiking difficulty), and trail maintenance information (number or location of tread drainage features), are also often assessed during basic trail surveys.

Sectional evaluations can be applied to segments of formal or ITs to characterize attributes such as hiking difficulty or resource condition. For example, condition class ratings that characterize increasing levels of resource impact can be applied to trail segments to characterize a trail network's overall condition. Alternatively, trail segments can be characterized in terms of their width, soil loss, or muddiness (Bratton *et al.* 1979). The trail segments can be defined and assessed by a fixed distance (e.g., at 100 m intervals) or by pronounced changes in the attribute being assessed.

Point sampling is a trail condition assessment method commonly applied to formal trails. Assessments are made at transects, generally spaced a fixed interval with a random start (Cole 1983, 1991), or in accordance with various strata such as level of use or vegetation type (Hall & Kuss 1989). Trail condition variables, including trail width, depth, muddiness, or substrate type, are assessed at transects and used to characterize the surveyed trail.

Problem assessment or census surveys are another common method, where continuous assessments record every occurrence of pre-defined impact problems (Cole 1983, Leung & Marion, 1999). Generally applied to formal trails, field staff record the starting and ending points for trail sections that are excessively eroded, wide, or muddy (Marion 1994). An evaluation by Marion and Leung (2001) concluded that the point sampling method provides more accurate and precise measures of trail characteristics that are continuous or frequent (e.g., tread width or exposed soil). The problem assessment method is a preferred approach for monitoring trail characteristics that are easily defined or infrequent (e.g., excessive width or secondary treads), particularly when information on the location of specific trail impact problems is needed.

Assessing Informal Trail Networks

A comprehensive review of the literature found very few reported examples of research or monitoring efforts focused on assessing IT networks (Marion *et al.* 2006). While ITs likely occur in nearly every protected area, managers have frequently ignored their presence, limiting monitoring efforts to formal trail systems. Furthermore, conventional trail condition assessment protocols are often difficult to apply to ITs due to their unique spatial characteristics (Marion & Leung 2001). IT segments are often comparatively numerous, short, and often braided in complex patterns (see Figure 2), creating sampling and assessment difficulties for point sampling or problem assessment methods (Leung & Marion 1999).

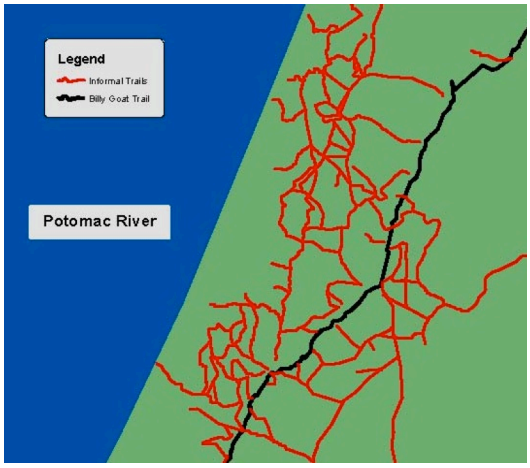

Figure 2. A "spaghetti" map showing the complex network of informal trails branching off the Potomac Gorge's Billy Goat Trail, C&O Canal National Historical Park.

However, scientists and managers have recently been focusing greater attention to the impacts of IT networks and to developing methods for assessing

and monitoring their impacts on protected area resources. Managers seeking to assess ITs must first consider two categories of attributes: spatial and resource condition. Spatial attributes include the location, arrangement, and lineal extent of ITs. Resource condition attributes include assessed degradation of vegetation, organic litter, and soils along ITs.

It is possible to assess most spatial attributes using scale-appropriate airborne remote sensing techniques if trails are not under concealing vegetation or when they are readily visible in leaf-off photography (Witztum & Stow 2004). Kaiser and others (2004) applied the best available techniques, including high spatial resolution (0.6m/pixel) digital multi-spectral imagery, digital image processing, and visual image analysis techniques, to detect and delineate new illegal immigrant trails in shrub lands along the US-Mexico border. They found that an automated linear feature extraction routine (Feature Analyst in ArcView GIS), followed by manual interpretation, delineation, and editing using false color infrared imagery, yielded the most accurate results. However, this method only resulted in 56% of the GPS surveyed trail locations matching by length, in part due to shielding overhead vegetation.

Extending this work, Cao and others (2007) evaluated three trail monitoring approaches and two types of spectral transformation to aid in locating trails in imagery. These procedures were designed to evaluate temporal changes in US-Mexico cross-border trail networks. They found that a map-to-image differencing approach was the most sensitive and reliable in detecting new trails, though no ground-based GPS surveys were conducted for comparison. For disturbed areas where the trail networks were extensive, Principal Component Analysis (PCA) of the image was more effective at enhancing new trails. For densely vegetated areas, a Normalized Difference Vegetation Index (NDVI) image yielded more interpreted trails. The authors stress that high quality, well registered, and radiometrically matched multi-temporal image datasets are needed for efficient and reliable trail map updating procedures. Imagery from different years must also be collected at the same phenological time and time of day to minimize errors due to vegetation seasonality and sun angles.

We conclude that these techniques are impractical for most protected area managers due to the substantial expense associated with image acquisition, technician expertise and time, and substantial inaccuracies associated with the methodologies used and concealing vegetation cover. A principal challenge for the Arctic Refuge is distinguishing visitor-created from wildlife-created trails – which cannot be done using remotely sensed data. Ground-based Global Positioning System (GPS) surveys are more accurate, use existing staffing and resources, and provide more immediate results. Point-based assessment methods include access (trailhead) and line transect surveys (described within the "Methodological Considerations for IT Monitoring" section). A highly efficient method is to inventory IT junctions with protected area roads, trails, or recreation sites, documenting junction locations with a recreation or professional grade GPS, odometer, or measuring wheel (Bacon *et al.* 2006, Marion & Cahill 2006). Alternately, an approach applying transects at fixed intervals within travel zones was developed for Zion National Park to document the number and location of intersecting ITs (Marion & Hockett 2008a).

Line feature assessment methods provide more comprehensive information on the spatial distribution and lineal extent of IT networks. This method requires a GPS set to collect line

features (tracks) as field staff walk all ITs within a management unit. Trail information from the GPS is then input to a Geographic Information System (GIS) for display and analysis of trail attributes (Wolper *et al.* 1994). This commonly applied protocol has been reported in several publications (Bacon *et al.* 2006, Cole *et al.* 1997, Leung *et al.* 2002, 2011, Leung & Louie 2008, Manning *et al.* 2006, Marion *et al.* 2006, Marion & Hockett 2008b). Advantages of such surveys, which census an area, include the ability to produce maps showing the location and spatial arrangements of IT networks, document the number of trail segments and aggregate lineal extent, perform GIS analyses to investigate proximity to rare flora or fauna or sensitive environments, evaluate landscape fragmentation, and perform other relational analyses.

Resource conditions along ITs can also be assessed to document effects on vegetation and substrates. A common method is to assign a condition class rating, generally five categories describing increasing levels of trampling impact from a faint trace to a barren and eroded tread (see examples in Manning *et al.* 2006 and Marion *et al.* 2006). ITs are broken into separate segments whenever condition classes change categories. Other tread condition indicators such as width and depth, and inventory indicators such as trail grade and vegetation type, can also be assessed using ratings and input as attributes of these segments (Rochefort & Swinney 2000). Resource condition assessments recorded for trail segments generally employ "typical" or categorical range data representative of the entire segment, resulting in some inaccuracies because these assessments are generally not measured. Measurements that are more accurate can be taken using a point sampling approach, generally employing a fixed interval between points with a random start. This method was employed by Wood and others (2006) to characterize informal tread width, depth, cross sectional area soil loss, and estimated total area of disturbance.

Study Area

The Arctic Refuge is a premiere wildland of 19.6 million acres situated north of the Arctic Circle in Alaska. Its boundary encompasses a vast area, providing visitors with seemingly unlimited opportunities to find solitude and experience wilderness. However, the primary means of access into and out of the Refuge is by aircraft, and the number of useable access sites are therefore limited. Areas such as the Atigun Gorge have become increasingly popular hiking destinations due to ease of access and proximity to the Dalton Highway. The Arctic Refuge is managed to maintain pristine conditions, including the absence of roads and trails. This provides visitors with a unique opportunity to engage with the land on nature's terms in seeking routes across the landscape, as opposed to following designated trails. While this provides a unique freedom for the visitor, it also bears a significant responsibility to adhere to dispersed hiking practices and low impact behaviors that will limit the formation of informal trails.

The Arctic Refuge is minimally managed, and is so vast that staff is challenged to conduct even the most essential visitor use management-related field efforts in areas of known management concern. For this reason, though staff has collectively visited what are understood to be the most commonly used areas, each individual staff member has had relatively few opportunities on the ground. The Atigun Gorge area of the Arctic Refuge was selected as the focal study area for this project because of relative ease of logistics (still, the area is an eight-hour drive north of Fairbanks), staff familiarity with the area, knowledge of visitor use patterns, and increased management concern related to potential visitor use impacts.

In addition to the documented increases in commercial guided day hiking and overnight trips to Arctic Refuge areas along the Dalton Highway, managers believe that non-guided visitation to this area has increased considerably over the past decade (Arctic Refuge 2011). The Dalton Highway, which was open to the public in 1994, allows relatively easy and inexpensive access to its western portions, particularly the Atigun Gorge area, which is recognized for exceptional scenery, wildlife values, and wilderness qualities. The Dalton Highway Corridor Management Area (DHCMA) extends five miles on either side of the Dalton Highway from the Yukon River to the Arctic Ocean. The ADFG currently uses the area five miles on either side of the highway to regulate hunting, limiting it to certified bow hunters. Hunting regulations in this area are intended to prevent overharvest of wildlife by limiting the number of hunters who use the area.

Licensed highway vehicles are allowed only on designated public roadways. To protect fragile tundra and wetland vegetation, recreational use of off-road vehicles (ORVs) or snow machines is prohibited by state law within the ten-mile corridor. However, people may access the area at any time by boat, airplane, foot, ski, or dog team, depending on the season. Federal Subsistence Management Regulations do authorize the use of snowmobiles, commonly referred to as snow machines in Alaska, for subsistence hunting and trapping by residents living within the Dalton Highway Corridor Management Area. However, any user can start outside the five-mile corridor on a snow machine and then cross the highway corridor to access other hunting areas or villages.

The Dalton Highway was designated a scenic byway by the State of Alaska, which continues to expand road infrastructure to facilitate tourism in northern Alaska. Managers predict that the

western portion of the Arctic Refuge will become a more popular destination for visitors as awareness and use increase. Continued improvements to the highway will expand visitation, particularly when rental car companies authorize their customers to drive this increasingly-paved road. Beyond the Arctic Interagency Visitor Center in Coldfoot, there are no developed facilities or formally constructed trails in areas such as Atigun Gorge, but greater numbers of visitors to this area could substantially increase day-hiking activity and, most likely, the proliferation of informal (visitor-created) trail networks in tundra habitat currently managed for dispersal (Monz et al. 2009).

The Arctic Refuge has not developed visitor use management strategies for the Atigun Gorge. Though educational materials to help visitors minimize their impacts have been produced, (see Appendix 4), no mechanism such as a permit requirement or visitor orientation insures those visiting the Atigun Gorge area receive educational materials and are aware of management concerns for the area. Another challenge faced by managers is the increasing recreational use of GPS units to navigate in the backcountry and to share favorite campsites and routes with other visitors via the Internet. Such technologies act to encourage repeated visitation along similar travel corridors and at specific camping locations which may have good views, water sources, and tenting sites (Van Horn 2007). The recent and continued development and improvement of road conditions and parking areas along the Dalton Highway will also increase hiking and backpacking into areas most proximate to the Dalton Highway. Finally, the limited number of access sites within the Arctic Refuge, particularly those along the most commonly visited rivers, used to stage float trips, act to concentrate visitor traffic on IT networks and around commonly used campsites. Regardless of the location, once increased visitor traffic occurs within an area, topography and woody vegetation act to concentrate traffic along the most easily traversed travel routes.

Arctic Refuge staff will clearly be continually challenged to sufficiently disperse repetitive traffic at these locations of concentrated visitation to prevent the development and expansion of IT networks and subsequent deterioration in their condition over time. Once informal trails and campsites appear they attract even greater use and experience in other protected areas reveals that they are generally permanent. It is exceedingly difficult to reactively deter their use and restore them to pristine conditions. Management experience at Denali NPP, a protected land area with similar historic visitation levels and regulations but contemporarily receiving greater levels of visitation, may help Arctic Refuge staff develop effective management practices into the future. Regardless of the specific actions selected, a strong proactive program of management will be needed to achieve and sustain a trail-less condition in Arctic Refuge's more frequently visited areas.

At the time of this report's completion, Arctic Refuge staff is in the final stages of a multi-year planning effort to revise its CCP. Over 600,000 comments were received from individuals and organizations with perspectives on the future management of the Arctic Refuge. Though many of these comments related directly to management of visitor experience opportunities and resource impacts due to visitor use, Arctic Refuge managers have decided that options for holistic visitor use management and Wilderness stewardship would be best addressed through public planning processes separate from the Revised CCP (Revised Plan). The general management strategies

prescribed in the final CCP will be used in the interim to manage visitor use during the development of the VUMP.

Managers have prioritized completing its Visitor Use Management Plan and concurrent Wilderness Stewardship Plan to begin immediately upon implementation of the Revised Plan. These step-down plans will address visitor use issues identified during both the CCP and the step-down planning processes. As part of these focused planning efforts, Refuge staff will consider levels of use, timing and distribution of use, and activities and behaviors of visitors, to evaluate a range of management actions appropriate to sustain, and restore where necessary, desired resource conditions and visitor experiences, that preserve wilderness characteristics and are consistent with the values for which the area was established. Managers will address visitor impacts and visitor information and monitoring needs; and may use education, site management, regulation, enforcement, and/or rationing/allocation to manage visitor use at Arctic Refuge, consistent with the VUMP.

Based on this step-down planning effort, managers may develop new educational requirements to better manage visitor use at the Refuge. Refuge staff recognizes the careful balance that needs to be taken between 1) providing educational materials and opportunities that encourage visitor actions that protect wilderness qualities on the Refuge, versus 2) allowing the public unimpeded access to the Refuge, while 3) not undertaking actions that draw increased visitor numbers to this fragile landscape. As visitor impacts on the ground increase over time, Arctic Refuge managers may need to do more of 1), at the expense of 2), while remaining true to 3). To accomplish this, staff continues to develop additional educational materials on the web and in pamphlet form to encourage appropriate visitor actions.

For more information about the Arctic Refuge Revised CCP, and the VUMP and Wilderness Stewardship step-down plans, please visit the Arctic Refuge website (http://arctic.fws.gov/ccp.htm).

Methodological Considerations for Informal Trail Monitoring

The spatial distribution of visitation can vary substantially within protected natural areas, ranging from very high near roads, landing strips, or popular attraction features to very low in remote inaccessible areas. The establishment of monitoring zones helps designate the priorities and intensities of trail monitoring efforts. The most remote areas require no monitoring effort if there is good reason to believe that no visitor-created trails exist. In contrast, more accessible areas require more intensive monitoring. Therefore, an initial step in trail monitoring is to establish zones to prescribe trail monitoring effort, from none to intensive. The following section describes a process for accomplishing this objective, though it is expected that over time, and as data is collected, that zones and their associated monitoring effort will be updated and revised.

Levels of Monitoring Effort

The type of trail monitoring employed will depend on the existing and expected number, extent, and condition of trails. Higher levels of monitoring effort will generally be applied to areas and trails that receive more intensive use and impact, and to areas where the level of use may be expected to increase rapidly, or the types of uses may be expected to expand in the foreseeable future. Several types of trail monitoring protocols are suggested, which are listed here and fully described in later sections.

- No trail monitoring within remote/inaccessible areas.
- Access survey – This method provides an efficient census of all informal trails leaving a road, formal trail corridor, or remote access site, documented by point data. The condition of informal trail segments can also be optionally assessed.
- Line transect survey – This method provides informal trail condition data assessed along one or more transects arranged perpendicular to the prevailing direction of travel within travel corridors or away from remote access sites. Informal trail locations are depicted by point data for each transect/trail intersection.
- Census mapping survey – This method provides comprehensive mapping data for all informal trails within a defined monitoring area, or an intelligent search through a travel corridor. The condition of informal trail segments can also be optionally assessed.
- Point sampling survey – This intensive survey method provides more comprehensive quantitative condition data taken at regularly spaced points along well-established formal or informal trails.
- Route finding experience survey – This method is an opportunistic assessment of the trail-less experience applied by visitors or backcountry staff during backcountry hikes.

Regardless of the protocol used, they should be replicated periodically (e.g., every 3-10 yrs) to document change over time. Monitoring could be initiated based on quick annual observations to see if any new impacts are apparent in a few of the access areas, or other observations that suggest increased visitation or changes in its distribution. Furthermore, surveys should only be conducted in the last half of the summer use season when evidence of human use on trails is most pronounced; and conducted to correlate with the same phase in phenological development each monitoring season.

Monitoring Zones

The geography and probable use patterns of the protected area can be used to initially identify potential trail monitoring zones (**Table 4**). These can be organized by distance from access points, travel corridors, and expected impacts.

Table 4. A categorization of possible monitoring zones in the Arctic Refuge.

Zone	Description
1	Road corridor areas with trails expected (due to expected high use, geography and/or ground cover susceptible to impacts)
2	Road corridor areas with no trails expected (due to expected use, geography and/or availability of durable surfaces)
3	Closed areas (e.g., critical habitat or habitat restoration closures)
4	Remote access points/travel corridors with likely trail formation
5	Remote access points/travel corridors with no likely trail formation
6	Remote/inaccessible areas

Roundtable Process

The key to establishing the zones is to investigate available data on known and suspected areas where trails are emerging or established. Gathering a group of the most relevant and experienced protected area staff to have a roundtable discussion, while drawing lines on maps, is a useful method. Other data sources are field observations of hiker contact locations; interviews of visitors, local guides, hike leaders; a survey of access points along roads; previous trail monitoring data; a plot of the locations and routes listed in guidebooks and reported by the public on the web; and known special destination or attraction feature points. The result of this effort is a map of the protected area's various monitoring zones, correlated to the suggested monitoring zone descriptions presented in Table 4. These are purposively selected by the staff present at the roundtable, with input as needed from other sources.

Data from the roundtable effort could be assembled into GIS layers to show discrete areas of probable human trail development defined by mapped polygons. Each polygon is then assigned an initial level of trail monitoring (type of survey method, frequency, and priority) as suggested by the guidance described in **Figure 2**. Additional layers include known and suspected trails and access points, formal trails, developed sites (roads and parking areas) and closures.

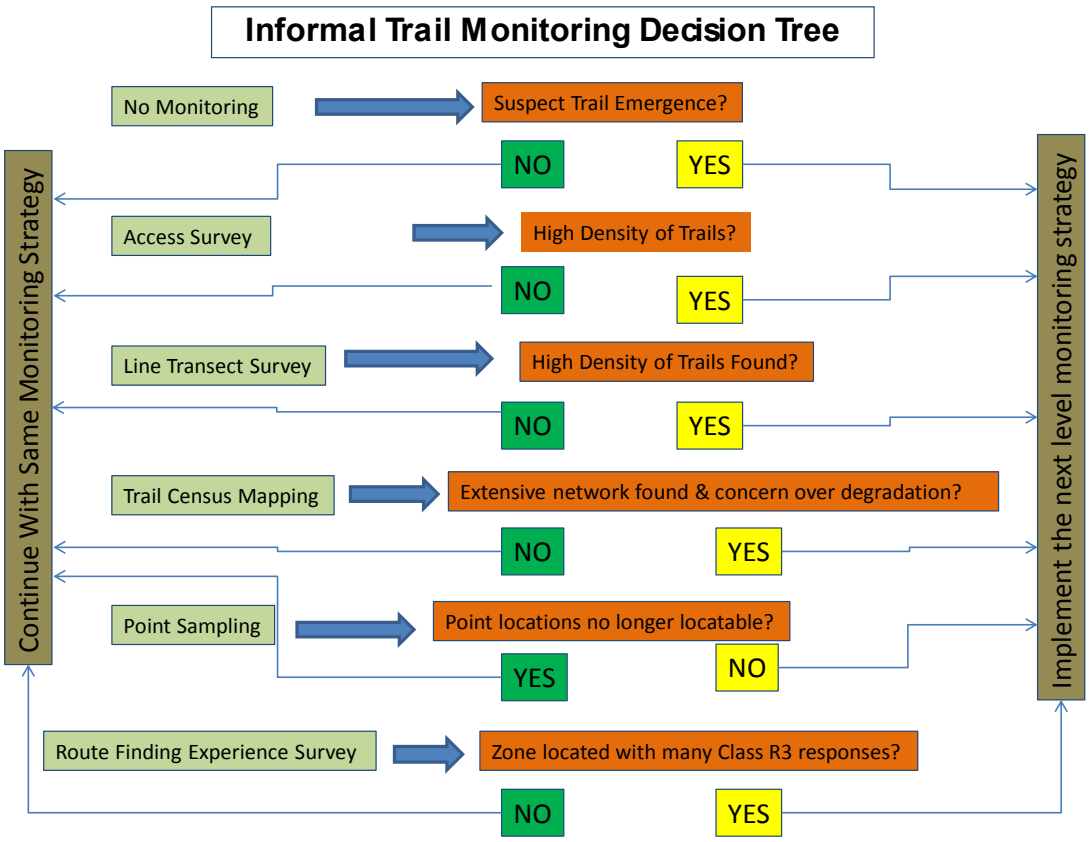

Figure 2. Suggested informal trail monitoring decision tree. Initial monitoring strategies are to be selected by managers and staff through a process of roundtable discussion and zoning.

In monitoring zones 2, 3, 5, and 6 trail monitoring will generally not be conducted, except as captured through the access survey. In some instances available information about use of certain areas may be incomplete. For the remaining zones, roundtable staff will need to decide between four types of monitoring. Generally, the route finding experience surveys are applied only to zones 1 and 4, areas where informal trails may eventually exist and trails are beginning to emerge. In such locations, trail conditions may begin to affect the experience opportunity for trail-less hiking, and yet are still potentially recoverable with proactive management. Similarly, point sampling would only be considered for zones 1 and 4, which might eventually contain well-used formal or informal trails with static alignments, and where informal trails currently exist. Line transect surveys are generally suggested as the most appropriate and efficient first step for areas that require some level of monitoring beyond the roadside trail survey. This survey requires about 25-35% of the time required to conduct the more comprehensive trail census mapping, which is generally more appropriate for higher-use areas with suspected or established networks of informal trails. However, where time permits, managers may also find that trail mapping provides useful information for documenting longer or discontinuous informal trails that do not occur in areas of dense trail networks, but may develop static alignments.

In considering whether to monitor an area or the type of monitoring to apply, consider both existing conditions and expected changes in use or management actions. For example, areas with few trails that are in acceptable condition may be less important to monitor, though documenting baseline conditions even for such trails remains an important management objective. However, areas in designated Wilderness, areas with few trails in poor condition or areas expected to see increased use or where management actions are likely, will generally be areas of higher priority for monitoring. The monitoring process should be a key component of adaptive management decision making.

As trail monitoring data is collected, the boundaries between the zones can be adjusted. For example, increased use in an area may lengthen trails that then allow day hikers to move further away from roads over time. This would extend the outer boundary of monitoring zones—with an accompanying change in monitoring prescription.

Protocol Development

The development of IT monitoring at the Arctic Refuge benefited from considerable additional research conducted at Denali NPP, where a companion study preceded the work at Arctic Refuge. Readers are referred to Marion & Wimpey (2011) for additional information on the development and field testing of the protocols suggested in this report. The Arctic Refuge study began while the Denali NPP study was well underway. It originated from initial peripheral involvement Arctic Refuge staff had in the Denali NPP study's refinements, applications through two summers of field trials, and further refinements through collaborations with recreation ecologists and Denali NPP staff. Essentially, the Arctic Refuge study began with the near-complete products of the Denali NPP study, which included extensive testing and refinement of a flexible array of trail monitoring protocols applicable to the kinds of terrain and vegetation types typical of Denali NPP.

Specific challenges addressed in the Denali NPP research included:

1) Development of descriptive condition classes with quantitative criteria for classifying informal trails ranging from "trace" or barely distinguishable trails, to well-developed trails with exposed soils in their tread. These were applied to different environmental settings and by different field staff, with analyses and subsequent modifications applied to improve assessment precision (consistency) and accuracy.

2) Development of alternative GPS-based trail assessment protocols that varied in their efficiency (application time), type of assessment protocol, and type of trail information provided. The resulting array of trail survey methodologies provides considerable flexibility in the selection of the most appropriate and efficient protocol that meets the needs of managers and budgetary/staffing constraints.

3) Development of trail survey methods applicable to tundra environments with the ability to distinguish between human-created and wildlife-created trails. While mixed use of some trails inevitably occurs, numerous criteria were developed and perfected to distinguish between the two uses.

During the summer season of 2009 a scoping trip was conducted that allowed for a preliminary determination of possible monitoring locations along the Dalton highway. Several different trail survey methods developed for Denali NPP were experimentally applied and refined based on field trials in areas along the Dalton Highway during this trip and another in 2010 (see **Figure 3**). Our protocols for this work followed those described in the Denali NPP report. These consisted of field trials with several individuals, including field staff applying and refining several trail assessment protocols in different environmental settings, and comparing assessment conducted independently by different field staff. Field staff also examined trails formed by wildlife in the area to ensure that they could be distinguished from human-created trails.

Study sites were selected based on several criteria, including knowledge of current visitor use, likelihood of vegetative impacts, parking availability, and proximity to the Arctic Refuge boundary. An inventory of resource conditions was conducted during the summer of 2010 where

all of the locations were scouted for observable informal trail formation and appropriate monitoring strategies selected and conducted (**Table 5 & Figure 3**).

Table 5. Locations assessed for informal trails.

Location Description	Type of Assessments Conducted
First pullout N of Galbraith Lake Rd	Access Survey; Line Transect Survey
Pullout across from Galbraith Lake Rd	Access Survey; Line Transect Survey
First pullout south of Galbraith Lake Rd	Access Survey; Line Transect Survey
Boundary of AR nearest to Dalton Hwy	Access Survey
North side of Atigun River	Access Survey
Atigun Gorge entrance	Access & Line Transect Survey; Census Mapping
Atigun Gorge ridge	Access Survey
Atigun Gorge waterfall & way back	Line Transect Survey; Census Mapping
Sheep notch	Access Survey; Line Transect Survey
First pullout S of Pump Station Four	Line Transect Survey
Trevor Creek	Line Transect Survey

One criteria used to distinguish wildlife from human trails is illustrated in this photo, which shows that humans purposefully walk on elevated clumps of grass, creating visible wear, which is not evident on wildlife trails.

The edges of wildlife trails are also generally cut straight down whereas human trails typically have more rounded profiles.

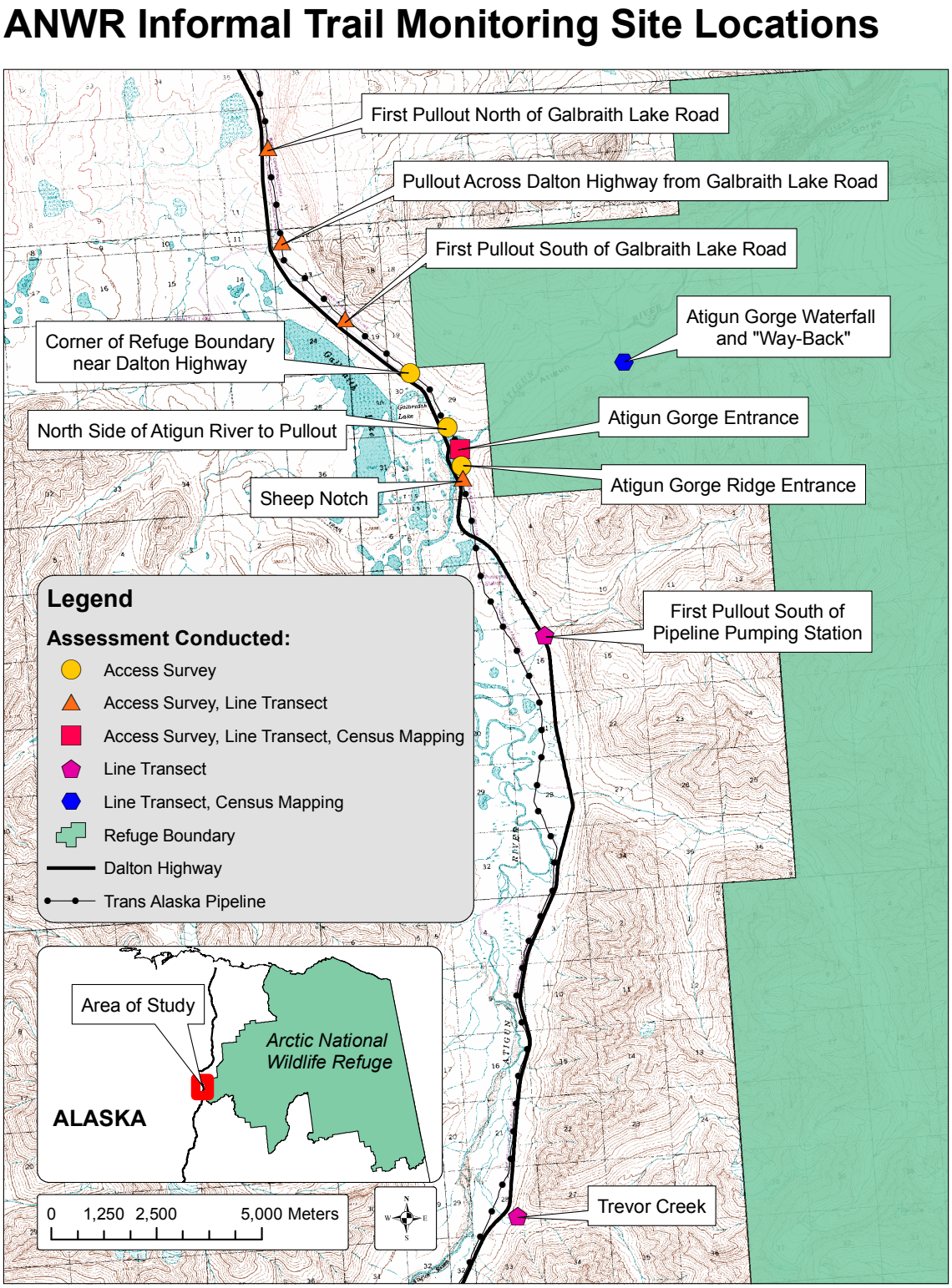

Figure 3. Location of the field work and monitoring site locations along the Dalton Highway adjacent to the Arctic Refuge.

Informal Trail Assessment Methods

The following section includes brief summaries of the type of assessments conducted at the aforementioned locations during the initial inventory conducted in summer, 2010. For full descriptions of the monitoring protocols refer to the information provided in the appendices.

Access Survey

This approach documents the number and distribution of all informal trails that intersect a road or formal trail corridor (Appendix 1). This is an efficient survey method that can be conducted quickly but it provides no information on trail alignments or destinations. This procedure involves a rapid search of the area immediately adjacent to the visitor access area and returns a count of the number of traces and informal trails present. This procedure provides a quick indicator of informal trail formation and can help determine whether more extensive monitoring procedures need to be initiated. Access surveys were performed in areas immediately adjacent to the Dalton highway and Trans Alaska Pipeline as indicated (**Table 5 & Figure 3**).

Line Transect Survey

This survey finds and documents the number, location, and condition of informal trails in areas near roads and formal trails (Appendix 2). This procedure involves establishing line transects perpendicular to the anticipated direction of travel in areas of likely visitor use. Once established, line transects can be relocated and monitoring procedures repeated during future efforts. Line transects were established and measurements conducted at numerous locations in the study areas where field staff possessing familiarity with visitor use patterns and the local geography expected travel routes to be more concentrated and likely to become emergent trails over time (**Table 5 & Figure 3**).

Census Mapping Survey

This approach documents the location, spatial distribution, and lineal extent of all informal trails within selected search polygons (Appendix 3). With continued monitoring, census mapping survey procedures allow managers to accurately track and characterize changes in the number, spatial distribution, and length of informal trails. Data can also be used to help decide which informal trails should be closed and to evaluate the success of management efforts to close selected trails or prevent the creation of new trails. Census mapping was conducted at two areas possessing observed or increased likelihood of informal trail networks during the 2010 assessment; Atigun Gorge entrance and the Atigun Gorge waterfall area (**Table 5 & Figure 3**).

Results and Discussion

Initial Assessment

Results of the initial assessment based on the aforementioned protocols illustrate the current condition of Arctic Refuge resources at these primary access locations (Tables 6-8, Figures 4-14). Initial assessments are often viewed as a "baseline" of resource conditions that provide information about current conditions. This information alone can inform management processes, particularly where formal standards of resource conditions have been established, and initial conditions can be compared to these standards. In other cases, the information provides an initiation point for ongoing monitoring to examine trends over time.

Baseline date for the transect line assessments (**Table 6**) and access surveys (**Table 7**) reveal a limited amount of trace and trail formation across study sites. The Atigun Gorge entrance area demonstrated the highest frequency of trail and trace formation via the line transect survey with traces and trails also visible at the first pull out south of Trans Alaska Pipeline Pump Station Four and at the first pull out south of Galbraith Lake Road. Census mapping was conducted at two areas (**Table 8**) with the Atigun Gorge exhibiting a total trail length of 595m in 15 segments and a total trace length of 733m in 36 segments. No traces or trails were found at the Atigun Waterfall and Way Back area.

GIS maps of all study locations (**Figures 4-14**) provide a visual representation of the above data summaries by location. These figures also illustrate the location of established transects which can be relocated and procedures repeated for future assessments of trends.

Table 6. A summary of line transect survey results by area

Area	Total Length (m) (Transect #)	Traces (#)	Trails (#)
First pullout N of Galbraith Lake Rd	245 (1)	0	0
Pullout across from Galbraith Lake Rd	213 (1)	0	0
First pullout S of Galbraith Lake Rd	313 (3)	1	0
Boundary of AR near Dalton Hwy	NA	NA	NA
North side of Atigun River	NA	NA	NA
Atigun Gorge Entrance	1740 (5)	10	2
Atigun Gorge Ridge	NA	NA	NA
Atigun Gorge Waterfall and Way Back	275 (4)	0	0
Sheep Notch	412 (3)	0	0
First pullout S of Pump Station Four	346 (2)	1	5
Trevor Creek	105 (1)	0	0

Table 7. A summary of access survey results by area

Area	Total Length (m)	Traces (#)	Trails (#)
First pullout N of Galbraith Lake Rd	147	0	0
Pullout across from Galbraith Lake Rd	220	0	0
First pullout S of Galbraith Lake Rd	155	0	0
Boundary of AR near Dalton Hwy	358	0	0
North side of Atigun River	NA	NA	NA
Atigun Gorge Entrance	512	1	0
Atigun Gorge Ridge	318	0	0
Atigun Gorge Waterfall and Way Back	NA	NA	NA
Sheep Notch	387	0	0
First pullout S of Pump Station Four	NA	NA	NA
Trevor Creek	NA	NA	NA

Table 8. A summary of census mapping results.

Area	Traces (#)	Total Trace Length (m)	Trails (#)	Total Trail Length (m)	Longest Trail	Longest Trail/Trace
Atigun Gorge Entrance	36	733	15	595	172	490
Atigun Gorge Waterfall & Way Back	0	0	0	0	0	0

Figures 4-13 will be modified: add the location of the river, the bridge, and the road for orientation purposes, and include the topographic layer to help "explain" the trace, trail, line transects; standardize scale of each map; for maps that do not include the Refuge boundary, identify the distance from and direction of the Refuge boundary.

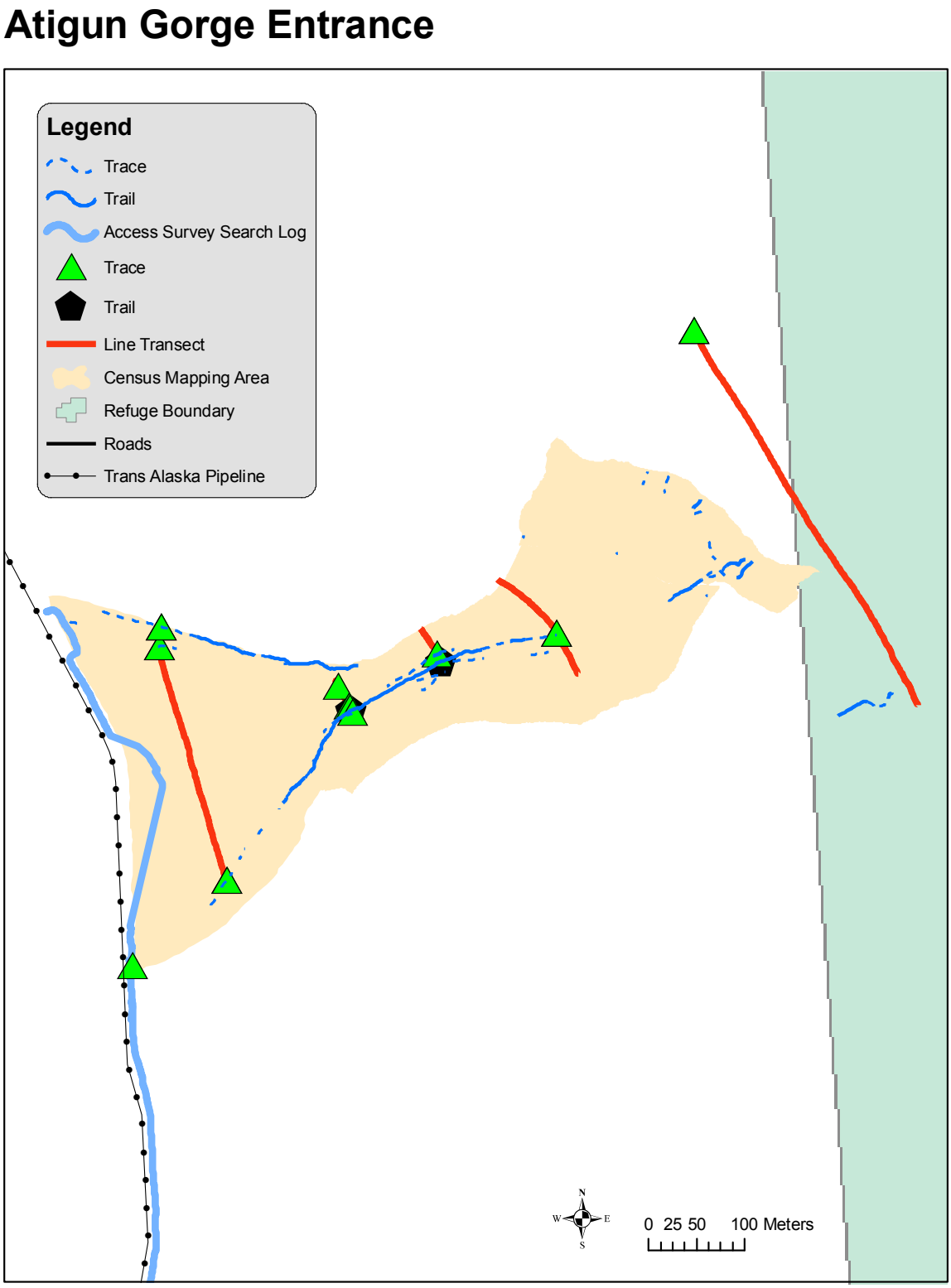

Figure 4. Atigun Gorge entrance area.

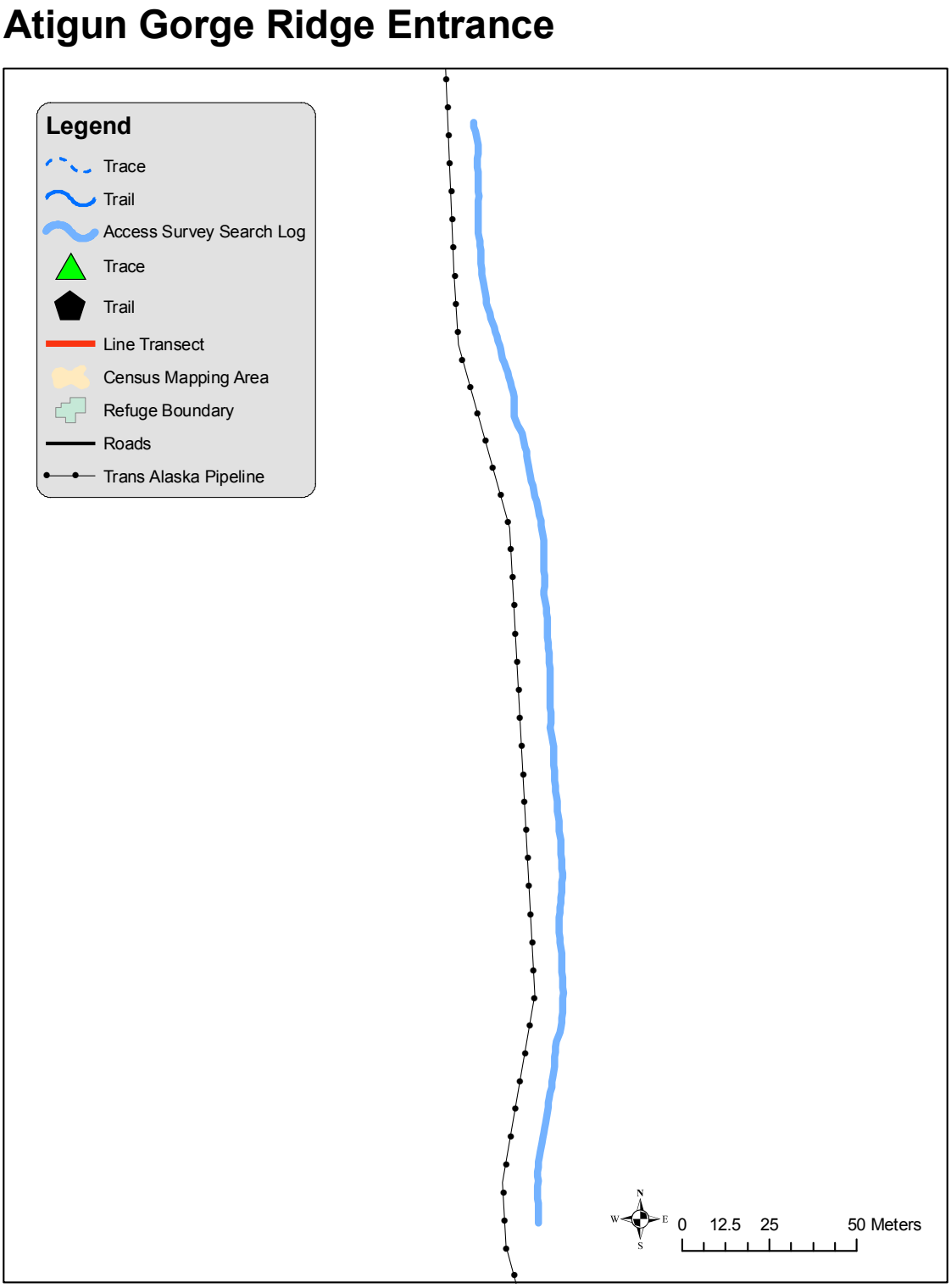

Figure 5. Atigun Gorge Entrance Ridge area.

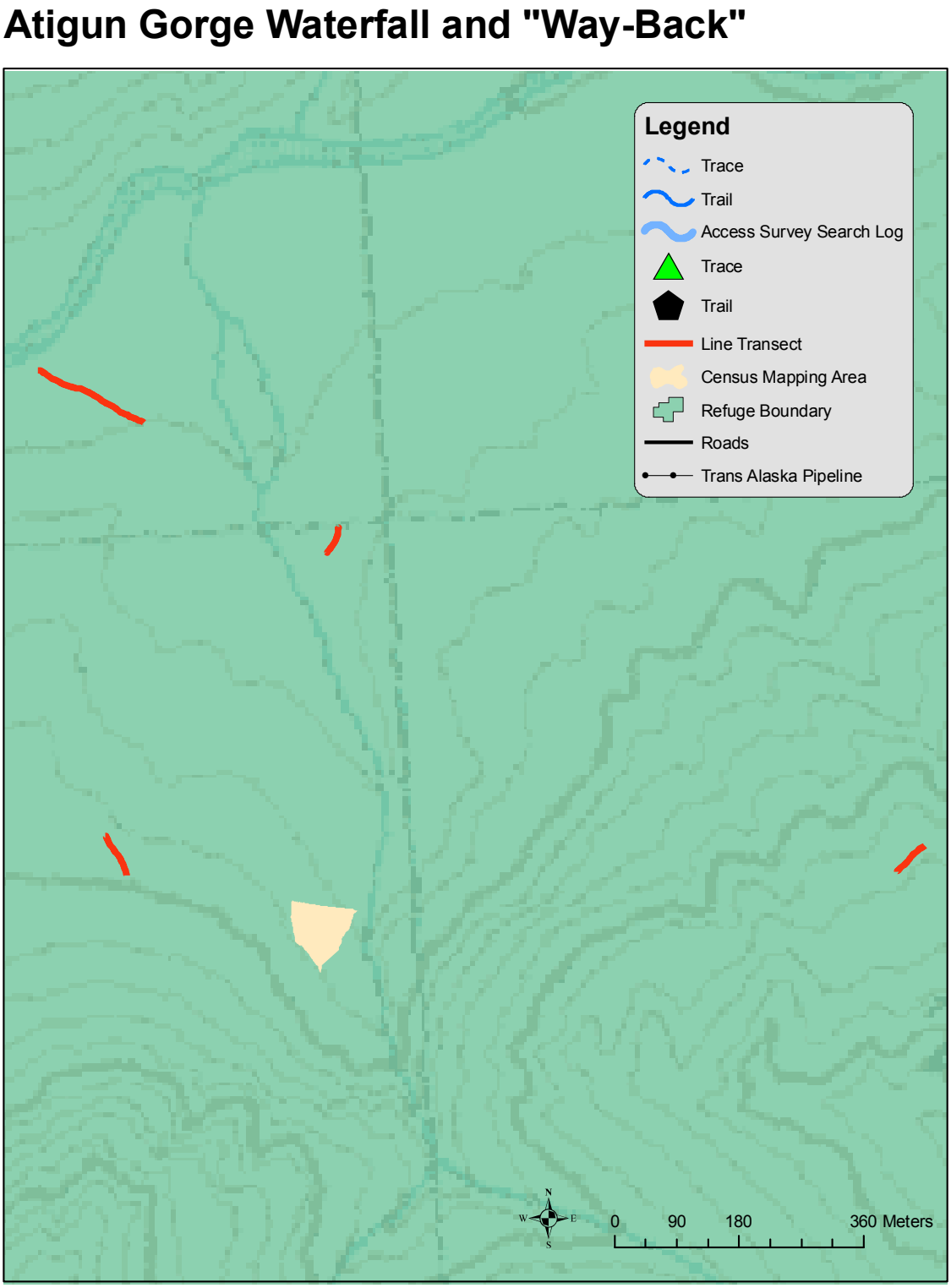

Figure 6. Atigun Gorge Waterfall and Way-back areas.

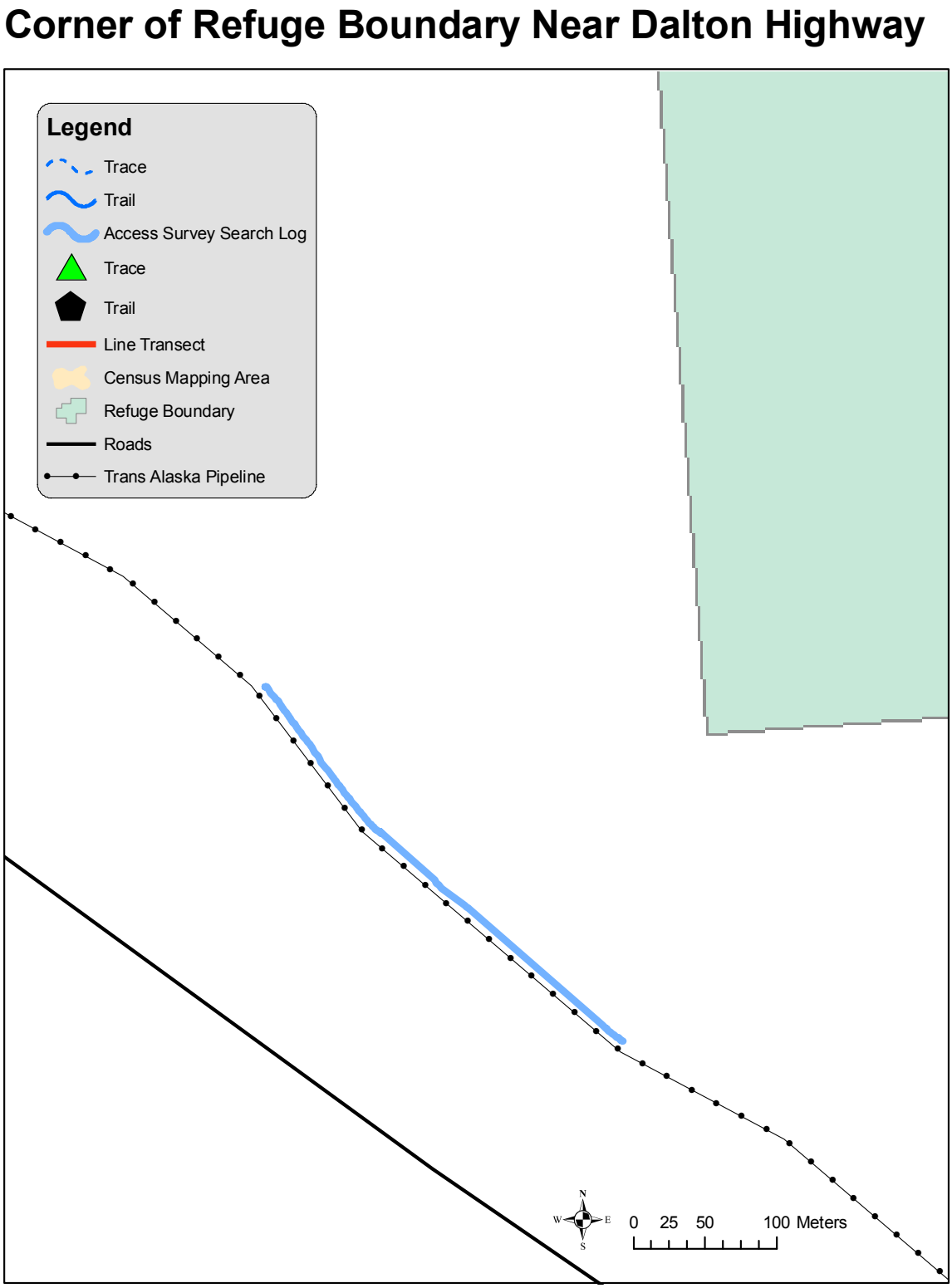

Figure 7. Corner of Refuge Boundary near Dalton Highway.

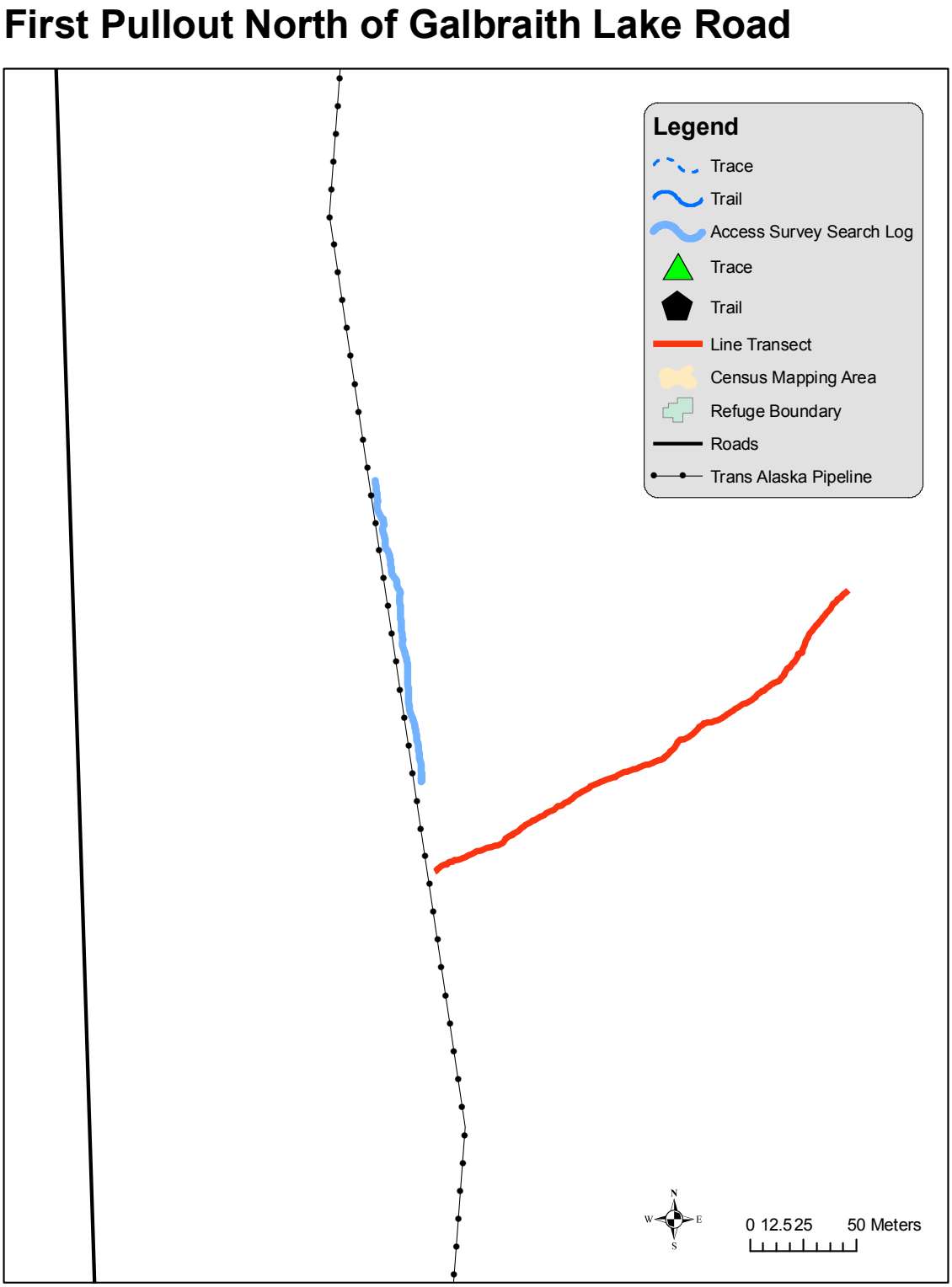

Figure 8. First pullout north of Galbraith Lake Road.

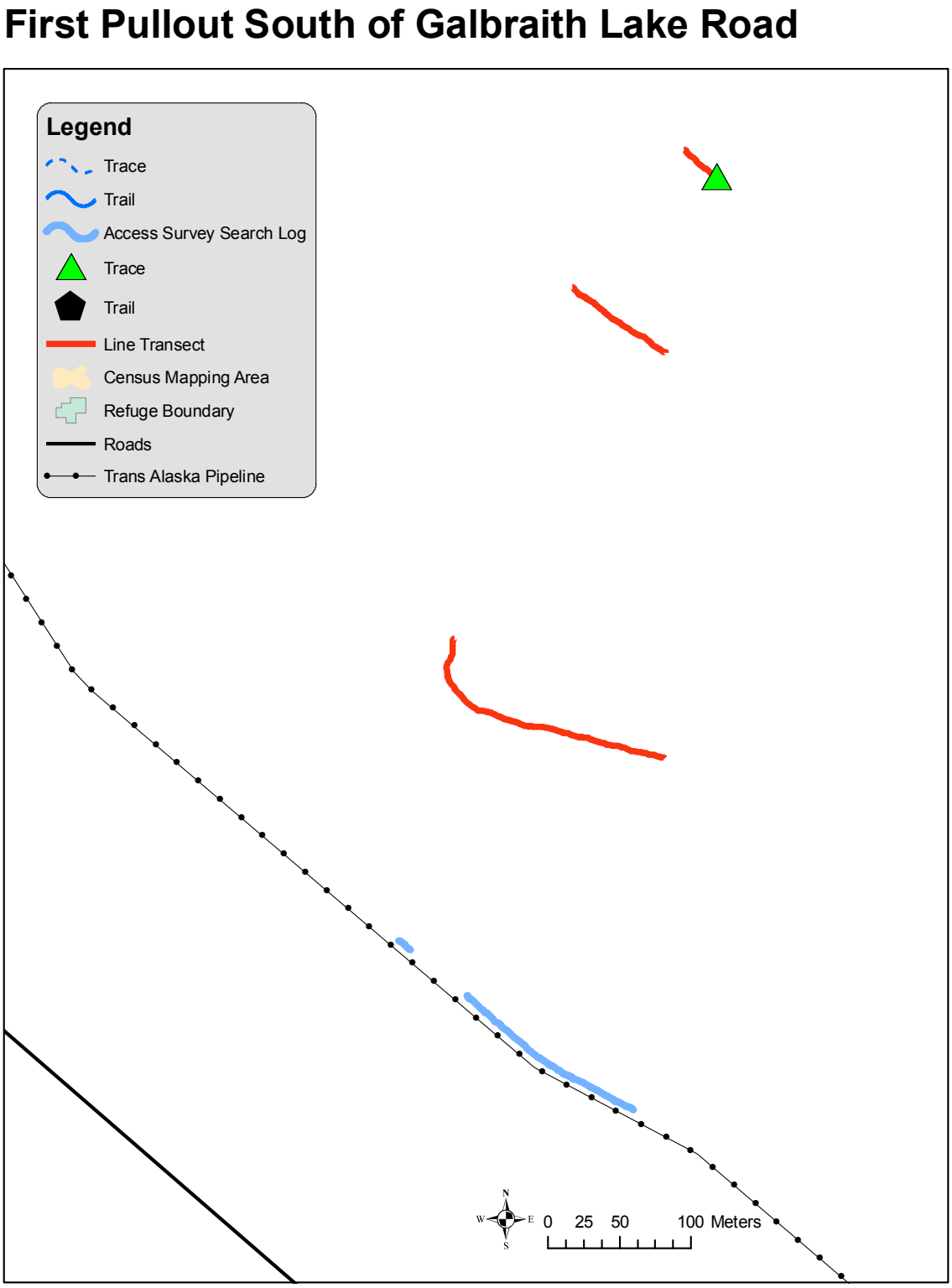

Figure 9. First pullout south of Galbraith Lake Road.

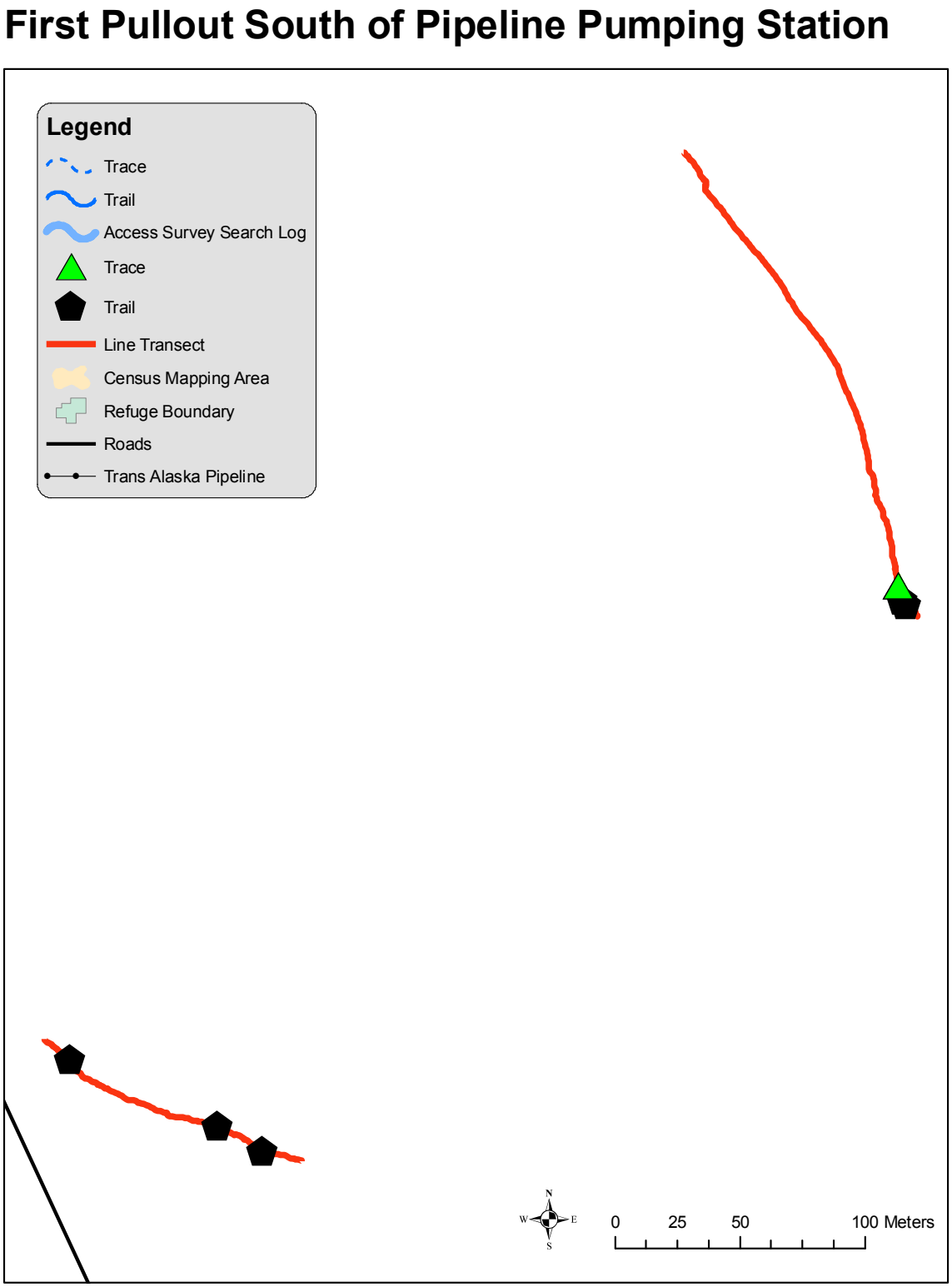

Figure 10. First pullout south of Pipeline Pumping Station.

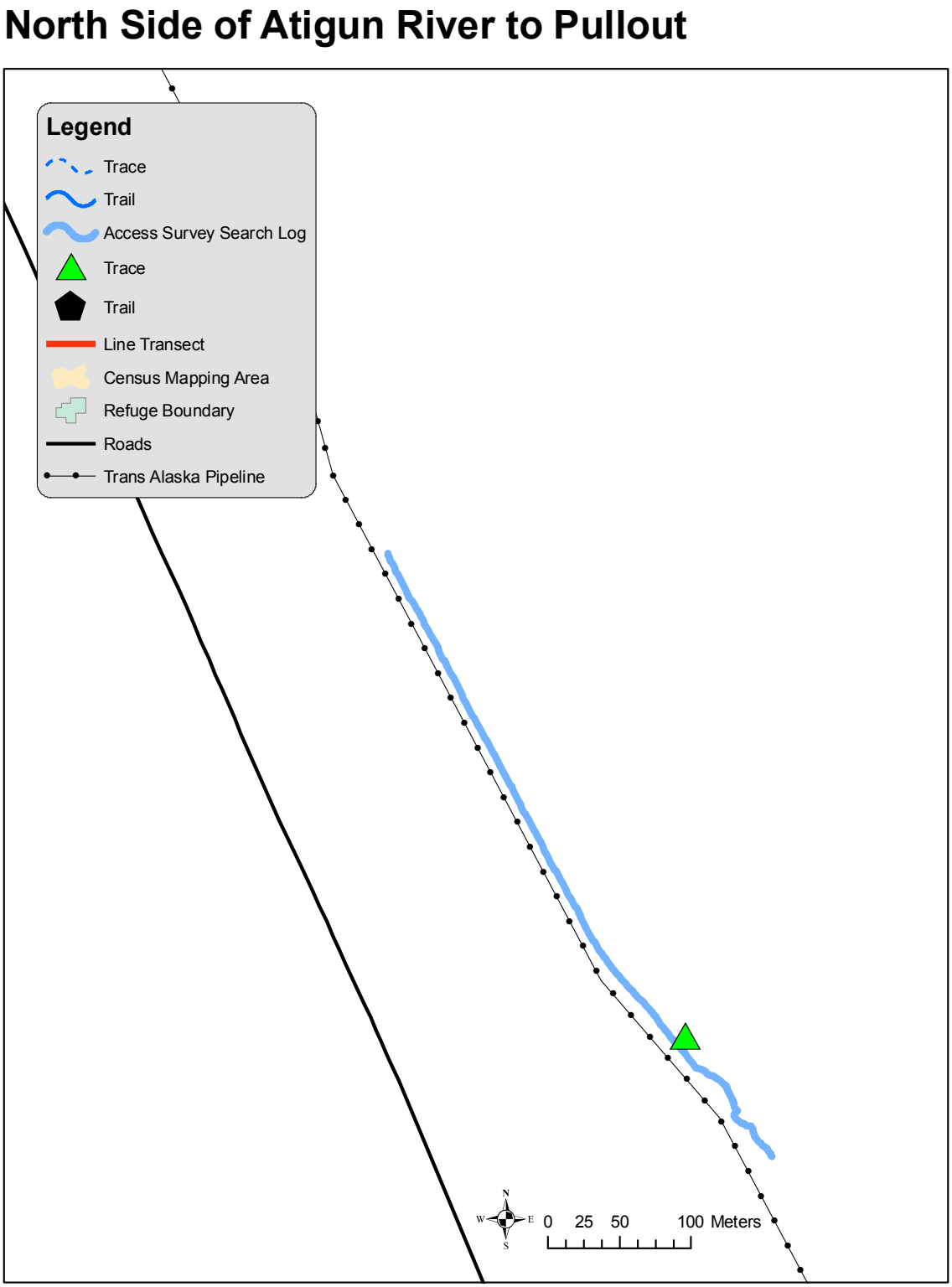

Figure 11. North side of Atigun River to pullout.

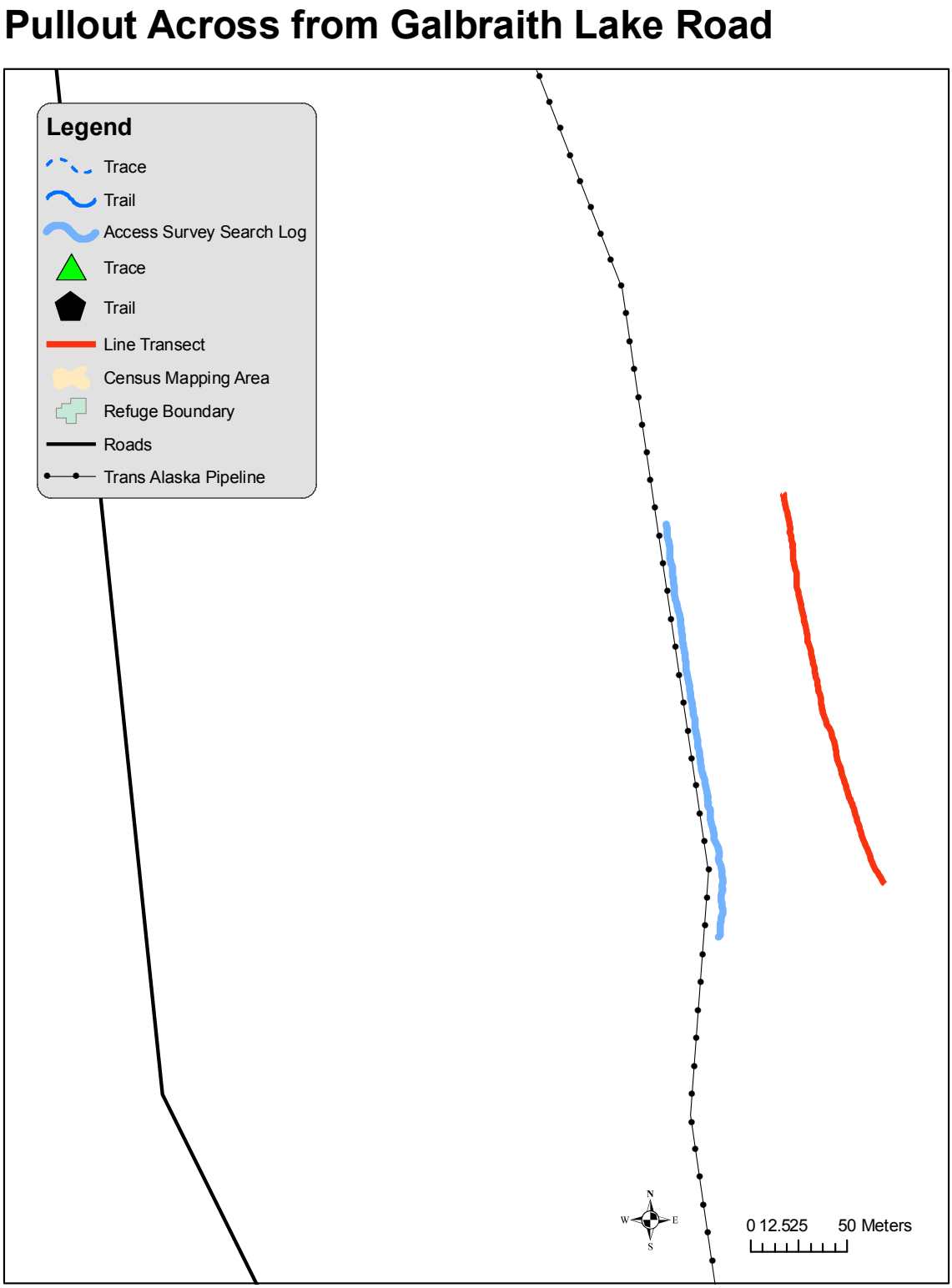

Figure 12. Pullout across from Galbraith Lake Road.

Sheep Notch

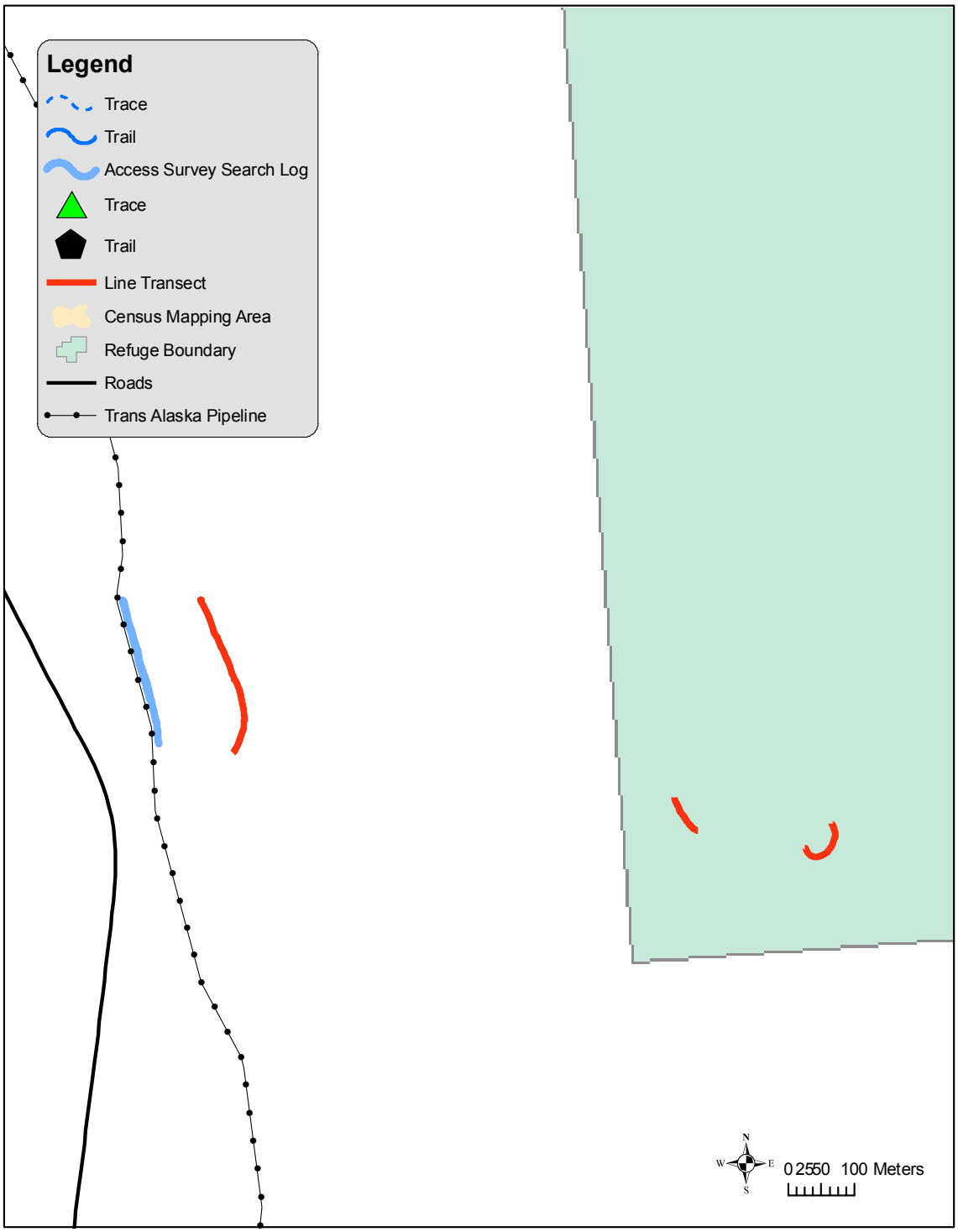

Figure 13. Sheep Notch.

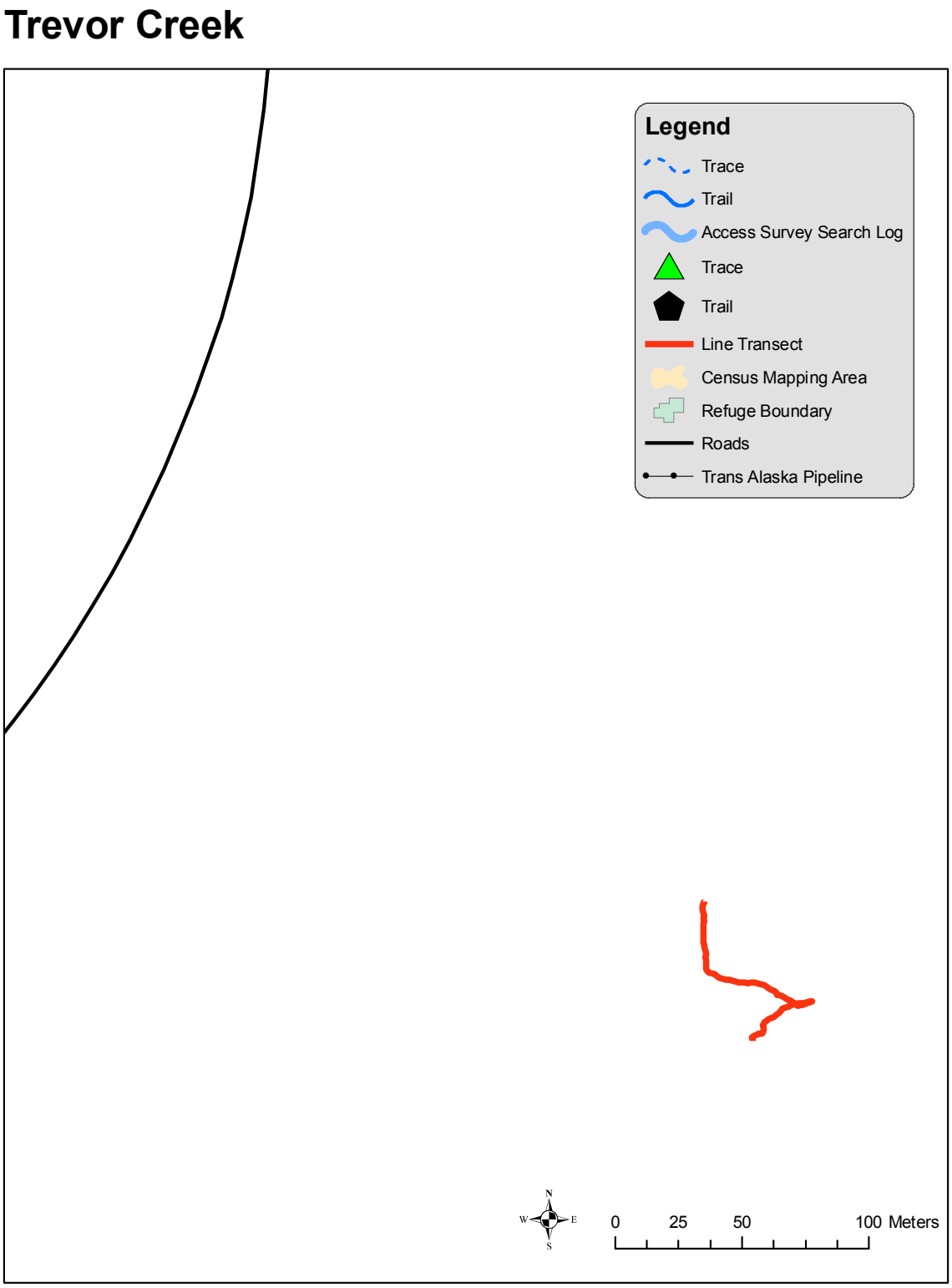

Figure 14. Trevor Creek.

Discussion

The full set of monitoring protocols are included in Appendix 1 for easy extraction and use. Paper copies of the field protocols should be photocopied onto waterproof paper and carried by field staff to consult. A listing of field equipment needed for each protocol is included for reference and should be checked by field staff prior to departure. Appendix 2 contains an overview of the monitoring workflow process, including a section on pre-fieldwork setup tasks. For example, most protocols require that the GPS units contain data dictionaries or background datasets such as search areas or line transects.

Following the completion of fieldwork, Appendix 1 also includes suggested data post-processing tasks and protocols for file naming and long-term storage. Monitoring data analysis tasks are also listed.

This research faced a number challenges: 1) protocols had to be flexible and highly efficient due to limited staffing and budgets, 2) traditional trail survey methods that have been developed for single, well-used/discerned, continuous trails were not necessarily applicable to the lightly used, discontinuous, braided trail networks commonly observed in fragile Alaskan tundra, and 3) some wildlife create trails that can be confused with visitor-created trails.

To address these challenges we developed a "toolbox" of IT monitoring protocols, allowing managers to select only those trail survey options and indicators that address their information needs, which may additionally vary by management zone. A roundtable decision tree process is suggested to assist managers in selecting the most appropriate protocol(s). The most efficient of these, the Access Survey, documents the number and distribution of IT's that intersect the Dalton Highway. All protocols incorporate GPS technologies with sub-meter accuracy to increase their efficiencies and facilitate quick computer input of spatial data for storage, analysis, and mapping.

We assumed the challenge of monitoring IT networks with discontinuous trails would be best overcome through reliance on survey options that focus on their point of original access (in protected lands with infrastructure, these are simply referred to as "trailheads") where use is generally highest and most concentrated; and on permanent line transects perpendicular to the prevailing direction of travel located in areas where topography or vegetation act to cause trail formation. Over the course of our work, it also became clear that for Arctic Refuge in particular, where early detection and proactive preservation will be key for retaining pristine wilderness characteristics, the RFE survey may prove particularly valuable for initial identification of new areas in need of monitoring, and could be conducted on an ongoing, opportunistic basis by recruiting field staff and frequent visitors knowledgeable of visitor use patterns willing to collaterally conduct RFE survey data at various remote access points suspected to be at risk for trace and trail development (see **Figure 2,** the suggested informal trail monitoring decision tree).

Census mapping of IT's can also be helpful, particularly if staff are well-trained and thorough. Access surveys can provide an efficient "early warning" to managers to consider the need for actions such as educational messaging or reduction in use levels. However, the results of our field effort indicate that to determine the most applicable survey methods for a given area, IT monitoring requires active involvement from interdisciplinary participants conducting round

table discussions that bridge resource subject areas (e.g., biologists are aware of wildlife population trends while field staff knowledgeable of visitor use patterns can confirm information imparted with on-the-ground observations of visitor use patterns). Traditional point sampling trail survey protocols are more problematic, particularly given the time required to search out if or where a surveyed trail might reappear, or deciding which braid to continue surveying if multiple trails are present. These methods may be applied best in areas under consideration for habitat or restoration closure to provide more detailed data about the efficacy of such a management action to protect resources.

This research also had to adequately address the challenge of monitoring IT networks in areas with large fauna, which also create and use ITs. When assessing visitor-associated trampling impacts an objective is to minimize assessment protocols that would be affected by changes in wildlife populations or their geographic patterns of use. We considered two options: 1) assess all trails (wildlife and visitor-created), and 2) omit trails created and predominantly used by wildlife when certainty is high. Following considerable discussion, field investigation, and protocol refinements, we opted for the second option and developed criteria for increasing the precision of such determinations. A Use Type indicator was incorporated within the protocols, with categories for: a) human, and b) mostly human/some wildlife. The accuracy of GPS surveys also allows field staff to return to the same trace or trail and determine, in the field, the use type assessment from a previously mapped trail segment, as well as compare initial field results with staff wildlife biologists when certainty may be low. These information inputs may help, over time, to determine the user type for such emerging trails.

Early in the fieldwork staff clearly had difficulty distinguishing the predominant use type for trails receiving both human and wildlife use. As a general practice we opted to instruct field staff to include and assess trails for which they could not determine a “predominant” use, knowing that, over time, if the predominant user type did end up being wildlife, trail conditions would not evolve to show human use patterns, but instead, would more clearly reveal wildlife use type characteristics, and may even recede into a trace over time. Any procedure that permits such judgments will inevitably introduce some measurement error into the monitoring assessments and temporal comparisons; and some areas do have large numbers of wildlife trails and their assessments would substantially slow field staff in the collection of unnecessary data that could also confound subsequent analyses without close coordination with staff wildlife biologists. However, the critical need for early trail emergence awareness is necessary for managers seeking to retain trail-less conditions, and as fieldwork progressed we continually refined our guidance, discovering an array of reasonably reliable criteria for differentiating wildlife trails from those used predominantly by humans.

Management Implications

Given that existing Arctic Refuge management guidance seeks to promote self-reliant route-finding, it is likely that a trail-less landscape, with the intent to prevent the creation and proliferation of IT networks, will be the long-term management vision for backcountry and Wilderness visitation, as opposed to travel along a continuous trail from a departure point to destination. The remainder of this report identifies prescription components to consider for managing trail-less conditions.

Employ Iterative Monitoring Protocols

Though Arctic Refuge visitation is considered to be low (even in its high-use areas such as Atigun Gorge) relative to other protected natural areas within Alaska, heavier visitation or cumulative effects of visitation year after year in some areas can create IT networks that may expand over time. Experience at Denali NPP suggests such a scenario, in the absence of an active program of visitor and trail management, may be inevitable. This research provides guidance and tools for implementing an IT monitoring program so that Arctic Refuge staff can document IT development, implement corrective management actions, and evaluate the efficacy of their actions and success in achieving management objectives over time.

In concert with the suggestion for a proactive educational program, this report presents Arctic Refuge staff with a flexible array of trail survey protocols for assessing and monitoring resource and experiential conditions on informal and formal trails. Managers require the ability to document the extent to which visitor-created trails are appearing and expanding and of changes in their tread conditions. Periodic application of monitoring protocols can inform management decision-making by providing quantitative data for a variety of indicators. Managers could evaluate changes in indicators, compare them to management objectives or numerical standards, and implement visitor or resource management actions to avoid or minimize degradations. To guide effective monitoring, upcoming visitor use planning should determine desired conditions and thresholds of acceptability for the presence of ITs; determine zones for monitoring IT and other impacts, address the acceptability of site-hardening across Arctic Refuge; develop management prescriptions to address hardened sites; outline educational strategies for successful outreach messages that compliment management prescriptions and monitoring efforts; and determine monitoring activities and intervals based on expected rates of change resulting from current and projected visitor use numbers.

This flexible array of monitoring protocols were developed, field tested, and refined. We suggest sufficient funding be allocated to more comprehensively apply an array of initial trail monitoring protocols to establish baseline conditions, and then forming an "informal trails working group" to develop coordinated actions that address IT creation and proliferation. This group can also help managers identify priorities for IT monitoring needs, identify management zones and monitoring protocols to be implemented within each zone, and guide the application of the monitoring program and subsequent reporting and use of data. While the five types of monitoring protocols can be flexibly and economically applied on an "as needed" basis, there is some benefit to obtaining sufficient funding to more comprehensively apply an array of protocols when initiating the program to establish baseline conditions for future comparisons.

In the future, following this initial survey, the working group may identify monitoring thresholds to evaluate which type of monitoring protocol to use and when. For example, *Census Mapping* might be applied to any travel corridor found to contain two or more ITs known not to be part of the same lineal extent. Based on Line Transect data, *Point Sampling* could be applied to any ITs found to exceed acceptable thresholds for width, erosion, or muddiness. The outermost band of Line Transect data might also be evaluated to identify which travel corridors retain one or more ITs leading into designated Wilderness or Wild River corridors possessing scenic values. These corridors might then be targeted for the *Route Finding Experience* surveys. Other topics for

consideration are the need for quantitative indicators and data required for future decision-making, or planning.

Identify Informal Trail Management Strategies

A range of management strategies and actions to avoid or minimize visitation-related resource impacts are available to protected area managers, including the development of formal trail systems expanding visitor access within road-less natural areas. In moderate to high use zones managers generally provide formal trails as part of a *containment* strategy that minimizes the aggregate areal extent of visitor impacts by concentrating traffic on durable tread surfaces (Hammitt & Cole 1998, Leung & Marion 1999c). Formal trails are generally designed, constructed, and maintained to accommodate intensive recreation traffic while minimizing trampling-related impacts. This strategy is based on a well-documented asymptotic use-impact relationship, whereby a majority of trampling impact occurs with moderate levels of traffic, and diminishing additional impact as traffic levels increase further (Cole 1992, Leung & Marion 2000, Newsome *et al*. 2002). Thus, confining trampling impacts to a limited network of formal trails avoids more widespread degradation caused by less structured patterns of visitor activity and traffic, such as informal trail networks.

In higher use areas, managers are frequently challenged by the development of informal (visitor-created) trails, and whether their use should be discouraged, prohibited, or tolerated. ITs that develop as shortcuts or duplicative and alternate routings, or traverse areas of sensitive habitat, rare species, or archaeological sites, are generally considered to be unacceptable (Error! Reference source not found.). However, ITs created to access attraction features or points of interest, like climbing spots and scenic vistas not accessed by formal trails, or through areas of constricting topography, like a narrow mountain pass, are often acceptable. In keeping with a containment strategy, accepting use of these ITs prevents the occurrence of more widespread impacts. However, sometimes ITs can proliferate into dense networks of duplicative routes with substantial amounts of trampling damage and "avoidable" impact. For example, an IT study at Potomac Gorge near Washington D.C. mapped 9.9 mi of ITs (46,663 ft^2 of trampling disturbance) on the highly visited Bear Island (**Figure 2**), which also has 2.0 mi of formal trails (Wimpey & Marion 2011b).

In low use zones, managers frequently implement *dispersal* strategies designed to prevent the occurrence of visitor impacts (Hammitt & Cole 1998, Leung & Marion 1999c). Land managers seek to avoid the emergence of ITs by promoting low impact outdoor practices such as those developed by the national Leave No Trace (LNT) program (www.LNT.org). Visitors are asked to disperse all activities on the most durable natural surfaces available to avoid or minimize trampling-related impacts. A common management objective in these zones is to keep them trail-less, preserving a natural landscape with no visible human impact.

Table 9. Impact management strategy by use level and zone, with characterizations of the acceptability to management of different informal trail (IT) types.

Impact Management Strategy	**Containment** *Mod-High Use Zones*	**Mixed** *Transition Zone*	**Dispersal** *Low Use Zone*
Formal Trails	Acceptable	Often Acceptable	Unacceptable
Duplicative/shortcut IT's	Unacceptable	Unacceptable	Unacceptable
IT's in sensitive/rare spp. habitat	Unacceptable	Unacceptable	Unacceptable
IT's to points of interest	Acceptable	Often Acceptable	Sometimes Acceptable
IT's in constrictive topography	Acceptable	Often Acceptable	Sometimes Acceptable

Consider Immediate Dalton-specific IT Management

Arctic Refuge, which currently seeks to disperse use where possible, is challenged at Atigun Gorge with the decision to determine whether the formation of ITs to points of interest and potentially where topography is constrictive, will be an acceptable condition. This report offers strategies to avoid further emergence of ITs, if managers do find that the presence of ITs is unacceptable. Unfortunately, general management experience with the dispersal strategy has revealed a number of challenges that limit its effectiveness that may apply to the Atigun Gorge area, including: 1) visitation levels that are too high to support effective dispersal, 2) limited availability of highly durable surfaces, 3) topography or vegetation that constricts traffic to common routes, and 4) inadequate educational programs that fail to communicate when and how activities should be dispersed, what durable surfaces are, and a compelling rationale for practicing dispersal. Educational programs rarely reach all visitors and communicating when they should use formal trails, informal trails, or disperse their traffic can be difficult. Encouraging visitors to forgo an IT for more challenging dispersed travel can be equally difficult, particularly when topography constrains route selection to a river-side bench or mountain pass route. Even the presence of a faint or discontinuous IT leading toward a destination or point of interest will attract visitors and act to reduce dispersal compliance.

Recreation ecology research has demonstrated that trails can develop at relatively low levels of traffic on less resistant and resilient vegetation and soil types (Cole 1987, 1995a,b, Marion & Cole 1996). ITs that develop in low use zones managed under a dispersal strategy are generally unacceptable (**Error! Reference source not found.**). Exceptions *could* include IT development to or near attraction features or in areas where topography or vegetation constricts traffic. In these areas, trails are created when visitor traffic is unavoidably concentrated /elevated to a level that exceeds the tolerance of native substrates to sustain it. Potential management responses include: 1) limit, discourage or prohibit use of the area, 2) enhance education efforts to promote greater dispersal, 3) implement site management to close and restore ITs, 4) tolerate and/or encourage IT use to avoid development of additional trails, or 5) design and construct resistant formal trails (generally inappropriate, except that the confounding combination of particularly

fragile vegetation types and minimal management capacities may, in this case, lead managers to consider construction of formal trails). A principal management challenge with options 4 and 5 is providing visitors with a consistent educational message regarding when to disperse activity or use a formal or informal trail. In the past, managers relied principally on logistical remoteness and benefitted from low visitor use levels to preserve trail-less conditions. These topics are addressed further in the Visitor Education section.

In areas where visitor use approaches levels suggesting long-lasting impacts, substantial, repetitive hiking on both moist and dry arctic tundra will quickly exceed its ability to heal, resulting in the emergence of ITs. This is supported by experimental research conducted in proximity to the Atigun Gorge study area on both moist and dry arctic tundra (Monz 2002). The experimental results suggest long-lasting impacts with as few as 200 passes by hikers in the same location. Disturbance and recovery of foot trails in well-drained upland tundra in the Arctic Refuge showed initial recovery when trampling of dwarf shrubs and mosses ceased, but recovery was dependent on maintenance of an unbroken soil organic layer (Grulke 1987). These studies show it is particularly imperative that Arctic Refuge managers, if seeking to retain pristine visual resource conditions in tundra landscapes, couple an aggressive education effort with preventing formation of traces and the initial emergence of ITs.

The potential for trail formation may be particularly acute at the Arctic Refuge's westernmost boundary, where the spectacular and easily-accessed Atigun Gorge draws visitors to explore this important wildlife travel corridor, and where it is presumed a significant number of undocumented visitors are travelling similar routes to attraction features within the area. Statistical estimates from a recent recreational study of Alaska residents suggest that Dalton Highway-based visitation to the Refuge may be substantially higher than what managers estimate (Stegmann et al., 2008). This study was designed to compensate for the lack of knowledge about recreational patterns of the overall Alaskan population. During the summer of 2007, Stegmann and her colleagues measured the recreation activities, settings, experiences, and benefits associated with summer visitors to the Dalton, Taylor and Denali Highways and the Fortymile National Wild and Scenic River. These areas are managed by the Bureau of Land Management (BLM) in the Central Yukon and Eastern Interior regions of Alaska. The study explored different levels of recreation demand with the purpose of supporting a Benefits-Based Management approach for recreation planning on BLM lands in these regions. Approximately 7% of all Dalton Highway survey respondents named either the area between Atigun Pass and Toolik, or the Galbraith Lake area specifically, as primary destinations (pers. comm. Fix).

Another recent study evaluates potential use of the Dalton Highway. The Alaska Residents Statistics Program (ARSP) (Fix, 2009) was a collaborative study among several Federal and State of Alaska agencies and the University of Alaska Fairbanks. Agencies participating in the ARSP survey included the U.S. Forest Service, National Park Service, Bureau of Land Management, Fish and Wildlife Service, Alaska Department of Transportation, and the Alaska Department of Fish and Game. This study measured travel around the state, and participation in activities, including Alaska resident travel to the Dalton Highway Corridor north of Atigun Pass and to the Arctic Refuge. The goal of the ARSP survey was to gather information regarding Alaska residents' recreational travel, including, but not limited to: recreation activities in which they participated throughout the state; use of facilities and types of areas such as undeveloped

backcountry, campgrounds, and visitors centers; visitation to public lands; recreation areas they no longer visit due to possible displacement; significant activities and reasons for participating in those activities; factors that contribute to quality of life, and demographic characteristics including how long they have lived in Alaska and where they lived prior to moving to Alaska. Though the data on Dalton Highway are contained within the Northern Region, and include all areas north of the Brooks Range between Gambell and the Canadian border, this study does provide limited insights into the gap of knowledge about where and how residents recreate in Alaska, which can aid in long term recreation planning. A significant percentage (11%) of the residents of Interior Alaska who responded to the survey said that they visited areas accessible from the Dalton Highway, including Arctic Refuge.

Continued improvements to the Dalton Highway will likely increase visitation. Over the past 20 years, the road surface is gradually becoming more vehicle friendly, with a much greater proportion of the gravel road being paved. Visitor services have increased along the highway near the Atigun Gorge with recent additions of a visitor center at Coldfoot, semi-developed campground facilities at Galbraith Lake and Marion Creek, and visitor parking facilities at several locations.

These improvements, in turn, increase awareness of the area and media depictions of the Dalton Highway and adjacent lands as recreational and hunting destinations. In considering the Atigun Gorge area of Arctic Refuge specifically, use impact theory, spatial analysis of recreation impacts, and management in other tundra environments in Alaska strongly suggests that sustained visitation at current levels and higher visitation will substantially increase the proliferation of informal trail networks on the tundra unless a visitor dispersal strategy is effectively implemented. This approach should convey educational messages teaching hikers and backpackers dispersed, low impact "tundra-walking" practices and encourage hikers to adopt and apply these practices. Existing education efficacy research suggests that this is indeed possible (supporting literature presented in Social Research Literature Review Section), and offers insights that can help managers to identify the most effective, positively-received message delivery tools appropriate for Arctic Refuge.

Land managers tasked with preserving pristine wilderness conditions have choices about what methods they can employ; implementing an effective education program targeted at each Atigun Gorge visitor promoting LNT practices consistent with arctic landscapes can increase the likelihood of success in meeting this management goal. If an aggressive education program is not implemented, but the condition of trail-lessness is the identified goal, land managers will likely need to set visitor use capacities at much lower thresholds and eventually restrict access sooner than if they implement a visitor containment strategy by designing /constructing formal trails at locations where informal networks emerge to access popular attraction features, and/or strictly limit access to maintain a very low level of visitation in Atigun Gorge. If none of these actions is undertaken (the status quo is maintained, with increasing visitation over time and accumulating tundra impacts from visitor use), we would expect to see the development of a duplicative network of interconnected informal trails from the road to the more prominent "attraction" features, resulting in maximum damage to once-pristine areas that will be hard to remove use from and repair. The areal extent of tundra impact from the "status quo" option is likely to be many times the resource impact associated with a formal trail, which in turn is considerably more

impact than under a successful dispersal strategy. While it is difficult to predict the rate of condition changes given the lack of data on visitor use patterns and densities in the area, informal trail network impacts could happen on tundra in as little as 2-3 years, given the availability of access of many of the locations inventoried.

Prioritize Effective Visitor Education

This research, and experience at Denali NPP, suggests that the most effective IT management tool is adopting a more aggressive education program that reaches the majority of visitors and promotes dispersed, low impact "tundra-walking" practices. Though outreach messages are available to Arctic Refuge visitors who seek out such stewardship guidance (Appendix 4), the majority of visitors currently do not encounter such resources before their visit. Even if visitors do obtain existing low impact outreach resources, as a result of the absence of clear management strategies for avoiding ITs, these materials lack the emphatic and concise language to effect visitor stewardship behaviors. The effective application of an education program is the most pressing management need to avoid resource impacts, preserve wilderness characteristics at areas of relative high use throughout the Arctic Refuge, be minimally intrusive on the visitors' experience, and delay or avoid the need for formal trail construction. A visitor education approach is supported by existing research using experimental trail designs, likely scenarios of visitor use along the Dalton, existing recreation ecology theory and current applications in other protected tundra areas in Alaska.

Transition zones between accessible high use areas and remote low use areas frequently present the greatest challenges to protected area managers, as neither a containment or dispersal strategy is entirely appropriate or effective in managing visitor impacts. Formal trails could be developed to sustain traffic to points of interest or through areas of constricted topography, but these may be viewed as inappropriate developments in some backcountry or wilderness settings. Managers are often willing to accept the creation and use of some ITs, provided they don't proliferate into duplicative routings, impact sensitive areas, or include particularly impact-susceptible alignments (Error! Reference source not found.). This is confounded by the necessity to switch educational messaging to visitors depending on the strategy in effect at discreet sites. Recent research reveals that visitors often choose less sustainable trail alignments and can create unnecessarily duplicative networks of trails that entail a substantial amount of avoidable impact (Leung *et al.* 2011, Wimpey & Marion 2011a). Furthermore, visitors may have difficulties distinguishing formal trails from ITs, and in deciding when to use trails or to disperse their traffic. A preferred strategy for transition areas might be to tell visitors to use well-established trails (formal or informal) when available while directing them to avoid faint trails to promote their recovery, providing explicit characteristic descriptions of what Arctic Refuge managers consider to be well-established trails and faint trails capable of recovery, and asking them to disperse traffic when in pristine areas. Managers could then perform subtle site management actions to redirect use and restore inappropriate or duplicative ITs and faint trails (see Site Management Options section).

Arctic Refuge managers can influence backcountry visitation-related resource impacts by regulating or educating visitors, or some combination of the two. National wildlife refuge managers have adopted educational messages to educate backcountry visitors using the

following media: websites, visitor centers, printed media, personal contacts, and through commercial use permitting and promotion of low impact practices and principles, such as those advocated by the Leave No Trace Center for Outdoor Ethics. Currently, many Arctic Refuge visitors do not come into contact with available educational messaging (see Appendix 4) and for those that do, the main thrust of the current educational program is visitor safety, primarily related to bears, weather and navigational preparedness, and stream crossings. Arctic Refuge outreach efforts could be refocused around reaching every visitor with low-impact messages, particularly in areas know to have IT emergence, and crafting concise messages with guidance for transition zones.

We also note that, though the national LNT program developed an Alaska Wildlands Leave No Trace Skills & Ethics booklet, we confirmed during this research, that there is a need for revising the current booklet with improved guidance for arctic and sub-arctic environments that can be informed by the results of this study and recent management experience. A suggested "first draft" of LNT practices for avoiding the creation of ITs based on a dispersal strategy for Denali NPP is included in **Figure 15**, could easily be adapted for use by Arctic Refuge and future editions of the LNT Skills and Ethics booklet series.

In addition to improving the clarity of educational messages for when to concentrate, and when to disperse use to avoid IT creation, and specificity of LNT educational practices related to avoiding IT creation and use, another salient management challenge is the effective communication of LNT messages to *all* Arctic Refuge visitors. Organizations that focus messaging to particular user groups, such as Backcountry Hunters and Anglers, Alaska Dog Mushers' Association, and Aircraft Owners and Pilots Association, should be targeted as part of the suggested effort to reach all visitors.

Figure 15. A suggested "first draft" of revised Leave No Trace practices for avoiding the creation of ITs based on a dispersal strategy.

LEAVING NO TRACE OF YOUR VISIT IN DENALI NATIONAL PARK

Denali National Park is managed as a six million acre trail-less wilderness, where formal trails are not provided and managers actively seek to prevent the creation and proliferation of informal (visitor-created) trails. The management objective is to preserve opportunities for visitors to experience a remote and pristine Alaskan landscape influenced only by natural processes. When traveling through the Denali wilderness you will need to develop and apply navigational and route-finding skills and much of your cross-country hiking will be "off-trail." While wildlife trails may occasionally be found and used, an important management goal is to not "link them up" as a continuous trail network. That would compromise the unique Denali wilderness experience that few U.S. parks are capable of providing. Be aware that cross-country navigation will substantially slow your hiking speed and is physically challenging, so allow ample time to reach your destination. The information and guidance below is provided to help you "Leave No Trace" of your Denali National Park visit. Accept the personal responsibility to help us achieve our stewardship objectives so your grandchildren can experience a pristine Denali wilderness when they visit.

DISPERSE YOUR ACTIVITY IN PRISTINE AREAS

Will your recreational visit require off-trail travel? If not, then stick to formal marked trails and recreation sites in developed park areas. Recognize that the resource impacts of your visit on formal trails and sites are quite low; when you venture away from these resistant trails and sites your potential for harming natural resources is substantially higher. Accept the personal responsibility to "*Leave No Trace*" of your visit if you must venture away from formal trails and recreation sites.

You may encounter informal (visitor-created) trails and sites, often only distinguishable from their formal counterparts by their lack of blazes, markings, or signs. Understand that off-trail traffic frequently leads to the proliferation of these informal networks of trails and sites. Furthermore, studies show that visitor-created trails and sites are more susceptible to resource impacts because they lack professional design, construction, and maintenance.

If your visit includes travel into low-use pristine areas, or far from formal trails and recreation sites in popular areas, disperse your footsteps and activities to avoid repeat traffic and visible impact. If each person takes a slightly different route, a distinct trail won't form because no single plant receives multiple footfalls. Your objective in these areas is to avoid concentrated hiking or recreational activity that leaves visible impact to plants and soils. Do not use informal trails or recreation sites, including those that are lightly impacted, to promote their recovery. Research shows that even a few passes by hikers or more than one night of camping can substantially delay their recovery to natural conditions.

The degree of dispersal needed depends on the substrates your group encounters. Rock surfaces that lack plant or lichen cover can tolerate concentrated traffic, as can barren gravel shorelines or dry washes, and snow or ice. Walking single file is acceptable only where there is little chance of trampling plants. If you must travel or camp on vegetation, look for dry grassy meadows and tundra – grasses have flexible stems and leaves that resist damage and recover quickly. In contrast, low woody shrubs and broad-leafed herbs are highly susceptible to trampling damage – avoid these. When in doubt, periodically examine the effects of your group's passage and minimize visible impact by increasing dispersal or use of durable surfaces.

Even low or inconsistent traffic along the same routes can lead to the development of trails. Cross-country hikers will discover that topography and vegetation often acts to concentrate their traffic to common routes with fewer obstacles. Resist this tendency if you see any evidence of trail formation and keep your group broadly dispersed, with single file traffic only on durable rock, gravel, or snow surfaces. Recognize that dispersed off-trail travel requires constant route-finding vigilance and is considerably slower and more difficult than hiking on trails. Plan your schedule to allow plenty of time for off-trail hiking! Failure to disperse your group's traffic will accelerate the formation of continuous trails that will attract further use and impact.

Dispersed Camping. In pristine areas, minimize camping impacts by selecting the most resistant site available and staying only one night. Avoid *any* pre-existing camping spots to promote natural recovery. When possible, also avoid areas highly visible to others, vegetated shorelines, and areas with bird nesting activity or recent signs of wildlife. Locate your cooking area on the most durable site available, like a large rock slab, gravel, or barren area. Unless durable surfaces are available, prevent trail creation by limiting the number of trips and varying your routes to water, sleeping, and cooking areas. Monitor the effects of your activities, concentrating use on the most durable surfaces or dispersing your activities—whatever's necessary to avoid creating lasting impact.

Before departing, naturalize and disguise the site—your objective is for no one to see or use the site again. Fluff up flattened vegetation and organic material and replace any rocks or sticks you may have moved.

Add leaf litter or pine needles to any scuffed up areas. If available, place a small log or large branch across your tenting and cooking areas to deter future use. Almost any forested setting can accommodate a single night of use each year without showing permanent effects; grassy areas can handle several nights. If you need to stay in one area longer, for example to conduct a wildlife study, plan on moving your campsite when lasting vegetation or soil impacts begin to show.

Review Social Research Literature and Site Management Options

Social science studies show that protected area visitors prefer education programs over formal trail construction in pristine settings, are highly supportive of educational programs and/or visitor use limits when protecting pristine settings, and are less supportive of constructing and hardening formal trails (supporting literature presented in Management Implications section). The "costs" paid by wilderness visitors of being exposed to educational messaging is minimal and offsets the benefits when compared to the consequences of not applying an educational approach.

Research suggests that the efficacy of IT management efforts is enhanced by integrating visitor education and site management actions For example, a well-used informal trail provides a strong visual "releaser-cue" to visitors, inviting its use even though educational efforts may have effectively communicated to visitors that they should disperse their traffic (Hockett *et al.* 2010). Research has found that visitors are more likely to engage in inappropriate behavior if they see others engage in similar behavior (Gramann & Vander Stoep 1987, Reiter & Samuel 1980), or in this case see evidence that others have used an IT. It follows that management efforts designed to make ITs less visible to visitors would be expected to further reduce their use and enhance natural recovery.

Research at Potomac Gorge near Washington, D.C., investigated and documented the efficacy of educational and site management options (Hockett *et al.* 2010). In an experimentally designed study, one treatment posted educational signs asking visitors to remain on a formal trail, along with small symbolic prompter signs attached to logs placed across all ITs branching off of the formal trail. A second treatment brushed up the initial visible portions of ITs in an effort to disguise them, or at least make them appear as low use trails. The educational sign treatment reduced observed off-trail traffic from 30% to 6.5% and adding the brushing treatment further reduced the off-trail rate to 2.0%. The brushing work in this study consisted of adding organic leaf litter to the trail treads, along with a few sticks and rocks. The intent was to naturalize the ITs appearance, rather than physically obstruct traffic. This was done because the objective was to protect native vegetation and rare plants – previous studies that used substantial brushing to obstruct IT use found that many visitors simply went around the obstructions, creating new trails. This was particularly true when the intent of the brushing treatments was not explained through educational signs (Johnson *et al.* 1987). Some visitors actively removed the brush. Though the decision to use signage at Arctic Refuge will be considered carefully, this research implies in some instances, their use may be warranted.

The implications of these studies for both Arctic Refuge and Denali NPP staff are that they could enhance the effectiveness of educational actions by adding or expanding efforts to conduct

physical trail closure work. However, in many subarctic and arctic environmental settings there is little organic litter or brush available to place on ITs and in some settings this action could make ITs intended for closure more visually obvious. This is likely acceptable as long as the work clearly communicates that the actions are intended to close the trails to use to restore wilderness conditions. For example, at Acadia NP managers have had success concentrating traffic on preferred sustainable ITs by clipping woody shrubs to keep them open and placing the clipped materials on adjacent duplicative ITs to discourage their use (**Error! Reference source not found.**). This could be an effective practice in higher traffic areas where duplicative trails have developed. Further development and experimentation with alternate site management treatments is needed at Arctic and Denali NPP to identify effective practices. In non-Wilderness areas (and some limited instances in designated Wilderness areas where extreme continued erosion of Wilderness qualities exists), we suggest such experimentation might include educational signs and/or symbolic prompter signs (Error! Reference source not found.). We suspect that in the Dalton Highway corridor, site management actions and signs may soon be necessary for the effective closure of ITs, even in concert with an aggressive education effort.

Figure 16. Example of a 3x4 inch prompter sign to deter IT use, and illustration of effective brushing work from Little Moose Island, Acadia NP.

Conclusion

Finally, the previous sections explored initial considerations for developing long-term IT management goals, complete with desired conditions, indicators, standards, management prescriptions, and an eventual monitoring plan for Arctic Refuge. Though this report identifies ways to effectively measure change in trail conditions tailored to Arctic Refuge, and specifically highlights prescriptions to consider in concert with effective monitoring for ITs, it does not identify acceptable levels of change in conditions; set in place a monitoring plan, commit to a specific protocol, propose certain use limits, or explore in-depth the social experience conditions that may be integral to trail-less wilderness characteristics Arctic Refuge's visitors may hope to experience. As noted in previous discussions and recognized by Denali NPP Backcountry Management Plan (BMP) guidance (**Table 10**), managers will need to make determinations such as when traffic should be focused on ITs, whether to enact closures of near-by duplicative ITs, and when visitors should be directed to disperse all traffic. Making these decisions and communicating appropriate site specific guidance to visitors will be a significant ongoing challenge. It is our sincere hope that this report illustrates pressing IT issues and useful considerations for their management to be addressed in future planning at Arctic Refuge.

Table 10. Access management tools included in the 2006 Denali NPP BMP.

Situation	Strategy	Application of Access Management Tools
No social trail formation; terrain allows dispersal or travel on durable surfaces (e.g., gravel river beds).	Keep use dispersal	Provide Leave-No-Trace education for backcountry users to encourage continued dispersal and travel on durable surfaces.
No social trail formation at existing use levels, but terrain does not allow for dispersal or travel on durable surfaces.	Maintain use at level such that social trail formation does not begin.	Provide Leave-No-Trace education for backcountry users; manage guided groups to limit use; monitor level of use to detect increases; and limit number of visitors if necessary.
Social trails are present and are either stable or deteriorating, but additional dispersal is possible.	Encourage additional dispersal to lower levels of use on the social trail.	Provide Leave-No-trace education for backcountry users and encourage voluntary dispersal coordination through a social trails working group (see #2 below).
Social trails are present but stable at existing levels of use; little opportunity for dispersal.	Concentrate use on social trail and limit use sufficiently to prevent deterioration.	Educate visitors or restrict them to social trail, and limit numbers of visitors if necessary.
Social trails are present and are deteriorating; additional dispersal is not possible because of terrain.	Lower use levels until condition stabilizes.	Limit number of visitors or use temporary closures to restrict use.
In addition, the National Park Service may temporarily close some areas around social trails to allow rehabilitation even if conditions are stable.		

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Appendix 1: Monitoring Protocols for Assessing Informal Trails in the Arctic Refuge

The survey methods included on the following pages provide flexibility in their application to meet management staffing constraints and information needs. Based on the guidance provided earlier in this document, select and apply the type of trail survey that most efficiently provides the information needed for management decision making. Protocols can be further modified but consider how changes might affect comparisons with past or future data, and archive all versions of the protocols and clearly indicate which version was applied during each assessment cycle.

Distinguishing Visitor & Wildlife Trails

Field staff will need to distinguish between informal trails that are primarily created and used by park visitors from those that are primarily created and used by "wildlife." Trails that are "mostly wildlife" are omitted from the Census Survey and are recorded but not assessed for resource condition in the Access and Line Transect Surveys. These criteria are included to help distinguish between these "type of use" determinations.

Spatial Criteria: Visitor trails frequently start at Denali NPP access points or near a high-use location, such as the Dalton Highway; and lead into less visited areas, often splitting into parallel routes but eventually becoming discontinuous and disappearing. These trails also lead to attraction features like vistas or follow traditional routes of visitor use. These spatial attributes can be a good indicator of visitor-created trails. Wildlife trails that intersect access points, such as remote landing areas, and generally have a "mirror" image trail directly across the road – look for these.

Visitor trails are generally "directionally consistent" over longer distances – consistently heading towards some destination. Visitor trails actively seek out and remain within the easiest topography and vegetation for human travel. Wildlife trails are generally more haphazard, they meander and often don't purposefully avoid wet areas.

Wildlife Sign Criteria: Knowledge about the ecology and natural history of the wildlife can assist decision-making. For example, sheep trails frequently descend steep slopes at narrow mountain gaps or to access mineral lick sites, while caribou trails frequently appear as numerous roughly parallel routes through flat to gently sloped terrain. Moose trails favor areas with willow thickets that people would generally avoid, and evidence of their browsing along the trail is common. In areas of woody vegetation, trails created by smaller mammals can be discounted because they are very narrow (<8 in) and go directly under branches that would obstruct human passage. These types of trails are the easiest to discount/omit.

Close inspection of the trail tread also offer distinguishing criteria. Animal feces/pellets and hoof or boot prints in or near the trail tread are common and fairly reliable indicators. Hoofs generally shear off the trail edges, which are often nearly vertical, where the sides of human trails are more rounded. The width of trails can be an important indicator; wildlife trails are narrower (often less than 8 inches) than human trails. Wildlife generally make no effort to detour around wet areas or to step on clumps of higher ground or vegetation, while humans do, leaving visually obvious trampled and flattened clumps of grasses as evidence of their passing.

Access Survey

Objectives

This survey documents the number and distribution of all informal trails that intersect a road or formal trail corridor. This is an efficient survey method that can be conducted quickly but doesn't provide information on trail alignments or destinations. Optional procedures are included for assessing trail conditions if needed.

Guidance

This survey could be conducted early in the monitoring process to inform the roundtable zoning process. This protocol can be applied to document the number and distribution of informal trail intersections with either a road or a formal trail. Staff training should focus on developing consistent judgment on when to assess or not assess faint informal trails – an array of photographs are included to assist in the consistency of these judgments.

Methods

Materials

- ✓ Field manual, data/photos from prior surveys, paper data forms and pencil for backup.
- ✓ Trimble GPS, charged battery(s), antenna, stylus, appropriate data dictionary.
- ✓ Tape measure, 15 m.
- ✓ Geotag-enabled digital camera that links with Trimble GPS position data (preferred). Option: use a standard digital camera, set it's time date/time to match the Trimble unit, and use a software program that matches date/time stamps to record location data to the photo file (geotagging).
- ✓ Telescopic antenna or presentation pointer (extending to 1.5 m).
- ✓ Logbook

Field Procedures: Survey staff should be familiar with the amount and distribution of hiking/backpacking use along the road or trail corridor to be assessed, particularly the locations where visitors are most likely to depart the road or formal trail corridor. Consultations with experienced public or private staff may yield important guidance and advice on locations where visitors commonly begin or end their off-road/off-trail hikes.

- Open TerraSync on the GPS and select the Data screen to create a new rover file. Select the Access Survey data dictionary from the pick list. Select the Map screen and open the Layers dialog. Select the Setup screen, and open the Logging Settings dialog.
- Ensure logging intervals for all features in the data dictionary are set to 1 second and are based on time, not distance. Logging velocity is unnecessary, set H-Star logging to Auto, and set Allow Position Update to Confirm.

- Drive the road or hike the formal trail and use prior information and personal knowledge to stop and carefully check locations where informal trails are expected. When driving roads, always get out and walk roadsides to locate trails in areas near pullouts, parking lots, and areas where visitor-created trails are expected. Record a "Search Log" lineal feature that documents the extent of your search. Away from pullouts, roadsides may be able to be surveyed by a non-driving vehicle passenger.
- Focus your assessment for informal trails at the outer boundary of human-caused disturbance associated with road/trail construction or maintenance work, e.g., look at the leading edge of undisturbed native vegetation, even if it is located some distance from the road or trail. Identify and assess separate trails at this interface, even if the trail immediately splits just beyond.
- Include all informal trails that have the following attributes: 1) treads that show clear signs of trampling disturbance created by this year's traffic from hikers and wildlife, 2) segments that extend at least 20 feet in length, 3) treads that are 8 inches or greater in width and that do not go around clumps of grass or underneath low-hanging branches, and 4) trails that remain clearly visible if you cover one eye (this eliminates faint trails that are indistinct without depth perception). Note that ordered gravel in gravelly substrates can qualify as a "Trace" trail. Figure 1 provides reference photos of relatively faint informal trails, termed "Trace" trails, to illustrate different types of resource changes that provide visual clues for discerning these trails.
- At the outer boundary of road or trail-related disturbance where you locate an informal trail, collect a "Access Trail Photo Point". Walk back toward the road or formal trail about 10-15 ft from the trailhead location and take a vertical photograph showing the trail in relation to the leading edge of vegetation and including the horizon near the top of the photo. Be sure to orient the camera in a downward angle to clearly document the trail's tread conditions – refer to Figure 1 for examples. Record a GPS point at this location. Tread condition assessments may be assessed using these photos.

Optional Condition Assessment Protocols

Based on staff information needs, the following indicators could also be assessed during this survey. These indicators provide additional information on the resource conditions of each trail assessed.

1) At the outer boundary of road or trail-related disturbance where you locate an informal trail, walk out the informal trail 20 feet and collect a GPS point using the "Access" point type in the data dictionary. Take a photo of this location from a height of 4.5 feet with a 50mm lens and clearly showing the tread condition and including the horizon with a distinctive feature. Record the azimuth from the camera to the waypoint location. At this point, assess the trail's type, use type, width, vegetation cover (on/off), and bare soil (on/off) at this point (see procedures below). If the trail splits before this point, assess these indicators for the last section of trail immediately prior to the split. Informal trail *Type* has two options: "Trace" trails are faint segments which still qualify for all four of the criteria listed above; "Trail" segments are more visually obvious and have treads with clear boundaries that allow the measurement of tread width and the remaining condition indicators below. Trace trails lack a

definable tread and cannot be assessed with the indicators below. *Use Type* options include: 1) human, 2) wildlife, and 3) mixed.

Notes: Wildlife trails often intersect roads or trails with matching trails on both sides; human use trails generally show flattened or worn tussocks of grasses (hikers consciously step to high ground/features, wildlife do not). Wildlife trail borders often have a sheared-off appearance (from hooves) and/or more deeply incised hoof prints, while human trails have treads that are more evenly compacted with rounded edges. Wildlife trails are generally narrow, less than 8 inches, and frequently have evidence of tracks, grazing disturbance, and animal scat (pellets). Human trails often start at roads or formal trails and consistently head for attraction features or destinations, often staying on high ground and avoiding wet areas.

2) *Trail Width (TW):* Measure the trail width between the outer trail boundaries. These boundaries are defined as visually obvious trampling-related changes in ground vegetation height (trampled vs. untrampled), cover, composition (e.g., grass, forb, lichen), or, when vegetation cover is reduced or absent, changes in organic litter (intact vs. pulverized) (see photo illustrations in Figure 2). The objective is to define the trail tread that receives about 95% of the traffic, selecting the most visually obvious outer boundary that can be consistently identified by you and future trail surveyors. Measure and record the tread width to the nearest inch.

3) *Total Incision (TI):* Extend a shock-corded tent pole section across the trail and beyond trail boundaries so that it rests on what you consider to be the pre-trail surface of the lowermost ground vegetation layer (i.e., on top of the moss/lichen mat and/or at the base of grass clumps and forbs). Use a tape measure to obtain a maximum value (nearest ¼ inch: 0, .25, .5, .75) from the bottom of the pole to the lowermost point on the trail tread beneath the pole (support it in the middle if it bends downward on wider trails). Subtract soil incision (next indicator) from this measure to yield a measure reflecting trampling-related compaction or loss of the vegetation mat.

4) *Soil Incision (SI):* Same procedures as above, but now align the extension pointer at the trail boundary with the interface between the upper soil surface and lower vegetation mat. Note that this interface may be below the tread, in which case record a value of 0 for this indicator. If soil loss has occurred, use a tape measure to obtain a maximum value (nearest ¼ inch) from the bottom of the pointer to the lowermost point on the trail tread. This measure primarily reflects the trampling-related compaction or loss of the soil. Arctic Refuge: substitute a Yes/No response for this measure based on whether soil loss has occurred.

5) *Vegetation Cover On-Trail (VO):* Imagine a 1 ft wide belt transect centered on the pole extending *between* the trail boundaries perpendicular to the trail. Within this band estimate the percentage of *live* vegetative ground cover < 1 ft tall (including herbs, grasses, low shrubs, live mosses, lichens (all colors), and any largely intact cryptogrammic crusts) rooted within the band using the coded categories listed below (see Figure 2). For this and the following indicator, it is helpful to narrow your decision to two categories and concentrate on the boundary value that separates them. For example, if the vegetation cover is either category 6-25% or 26-50%, you can simplify your decision by focusing on whether

vegetative cover is greater than 25%. Alternately, consider that analyses will use the midpoint values for these categories so it may be helpful to base your decision on which midpoint value is most representative of the trail tread cover. Cover categories:

0-5% (1=2.5), 6-25% (2=15.5), 26-50% (3=38), 51-75% (4=63), 76-95% (5=85.5), 96-100% (6=98)

6) *Vegetative Ground Cover Off-Trail (VF):* Assess vegetation cover in an adjacent, untrampled off-trail location several feet beyond trail boundaries. The intent is to locate a "control" area that depicts what the vegetation cover on the trail tread would resemble had it never been trampled. Select a control that has the same proportion and size of rocks as the tread quadrat. In instances where you cannot decide between two categories, select the category with less vegetative cover. The rationale for this is simply that the first visitors would tend to select a trail route with the least amount of vegetation. Note that if some of the trail substrates would likely be barren due to exposed rock, then the control substrates or control vegetation estimates must reflect that.

7) *Bare Soil On-Trail (BO):* As in #5 above, but estimate bare/exposed soil cover, defined as rocks, gravel, roots, and exposed soil of all types, including organic soils with pulverized organic litter (see Figure 2). Total cover for each band transect should approximately equal the sum of your mid-point estimates for #5, #7, and organic litter cover. Omitted for Arctic Refuge.

8) *Bare Soil Off-Trail (BF):* As above, with the cover estimate of bare soil (not organic litter) made in the same off-trail location used for the vegetation assessment. Omitted for Arctic Refuge.

9) *Tread Problems (TP):* Record as 1) None, 2) Mud <1", 3) Mud 1-3", 4) Mud >4", 5) Active Erosion Occurring. Omitted for Arctic Refuge.

Figure 1. Reference photos illustrating faint "Trace" informal trails defined by the effects of trampling disturbance, including: 1) reduction in woody vegetation, 2) flattening, abrasion, or reduction in herb and grass cover, 3) compressed or reduced moss and lichen cover, and/or 4) sorting or disturbance of rocks.

Cover Categories: 1 (0-5%), 2 (6-25%), 3 (26-50%), 4 (51-75%), 5 (76-95%), 6 (96-100%)
Vegetation (V): Includes all plants <6" tall, including thin mosses and lichens.
Bare Soil (B): Includes bare soil, gravel, roots, rock, and water (excludes organic litter)

Figure 2. Representative photos illustrating the placement of telescopic antenna extending beyond trail borders and from which is measured veg/soil maximum incision to deepest spot along the tread. Trail width is assessed along the antenna between the blue lines. Vegetation and bare soil (see definitions and cover categories above) are assessed for the trail in a band 1 ft wide centered on the pointer. See reference assessments included in yellow on the photos. Off-site vegetation and bare soil values are assessed in representative undisturbed areas several feet beyond the ends of the pointer.

Line Transect Survey

Objectives

This survey finds and documents the number, location, and condition of informal trails in areas near remote access points, roads and formal trails.

Guidance

Line transect survey (LTS) areas are identified by the roundtable procedure. One or more line transects are established within these areas roughly perpendicular to the anticipated direction of travel. All informal trails (including "Trace" trails) that intersect with each transect are inventoried as point features, with assessments of use type, trail width, maximum incision, vegetation cover, and bare soil (described in the Access Survey section) recorded for each trail. LTS is less labor intensive than census trail mapping, yet provides meaningful data on trail locations and conditions for decision-making. Generally, LTS transects are placed close to roads to pick up the start of informal trails, at locations where topography or vegetation constricts traffic, and at more distant points to see if informal trails are continuing into the backcountry. When possible, place an adequate number of transects to generate a sufficiently large "N" of sample points to characterize informal trail conditions.

Methods

Materials

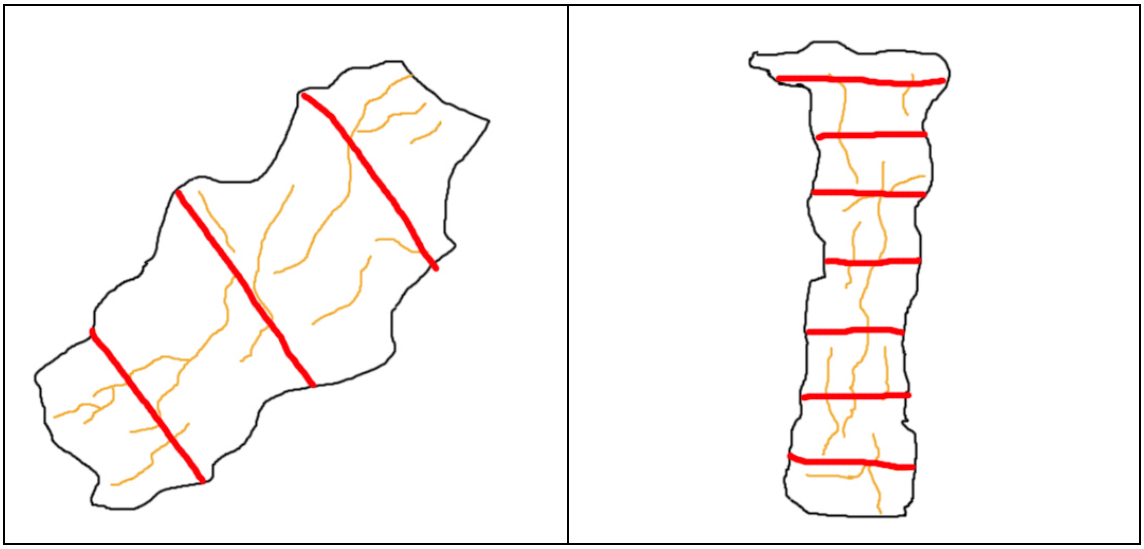
- Field manual, data/photos from prior surveys, paper data forms and pencil for backup.
- Trimble GPS, charged battery(s), antenna, stylus, appropriate data dictionary, and LTS polygons.
- Tape measure, 6 ft.
- Compass
- Telescopic antenna or presentation pointer (extending to 4 ft).
- Logbook

Field Procedures: Load into Trimble GPS's TerraSync mapping software the boundary polygons circumscribing areas to be surveyed and configure the data dictionary for data entry.

- Open TerraSync on the GPS and select the Data screen to create a new rover file. Select the LTS data dictionary from the pick list.
- Select the Map screen and open the Layers dialog. Select "Background Files...," locate the appropriate mapping area polygon layer and designate it as the background layer. Conduct all mapping efforts in the field within this polygon, making note for later revision if the boundary polygon needs to be modified based on the field visit.
- Select the Setup screen, and open the Logging Settings dialog. Ensure logging intervals for all features in the data dictionary are set to 1 second and are based on time, not distance.

Logging velocity is unnecessary, set H-Star logging to Auto, and set Allow Position Update to Confirm.

- Begin by exploring the previously defined LTS area to get a sense of its size and location, likely direction of travel for visitors, and presence of informal trails. Reassess the boundaries of the search polygon developed by the roundtable process and record point and/or polygon features and descriptive notes if needed to document alterations based on local topography, existing trails, or possible additional areas where trails could develop.
- Identify the most appropriate locations for one or more transects that cross the entire area roughly perpendicular to the direction of visitor travel. These can be placed to assess trail numbers both close to and further away from the road or formal trail to document decreasing trail numbers with distance. They may also be placed strategically at locations where trails are most likely to form. Examples include patches of woody vegetation, areas where topography concentrates visitor traffic, and areas that might attract visitor use or traffic. A minimum of three transects should be defined, fewer if no trails are present, more if the area extends a long distance with trails throughout. The spacing between transects and their alignment will vary according to the size and shape of the LTS area (Figure XX 3).
- Select and navigate to an endpoint for the first transect. Identify a transect alignment that is most likely to cross informal trails that may be discontinuous and identify a physical feature located beyond the end of the transect to guide your line of travel.
- Start recording a "LTS Transect" feature to document the transect you walk, then take, record, and follow a transect compass bearing as you walk the transect, looking for and assessing (collect/nest an "LTS Point") each informal trail you encounter with the seven indicators included in the optional Access Survey protocols (see also guidance in Figure XX 2).
- Assess all informal trails, including "Trace" trails as defined in the Access Survey section.
- Move to the next transect and repeat these steps. When all transects have been collected, record some summary notes about the LTS area and then move to a new LTS area.



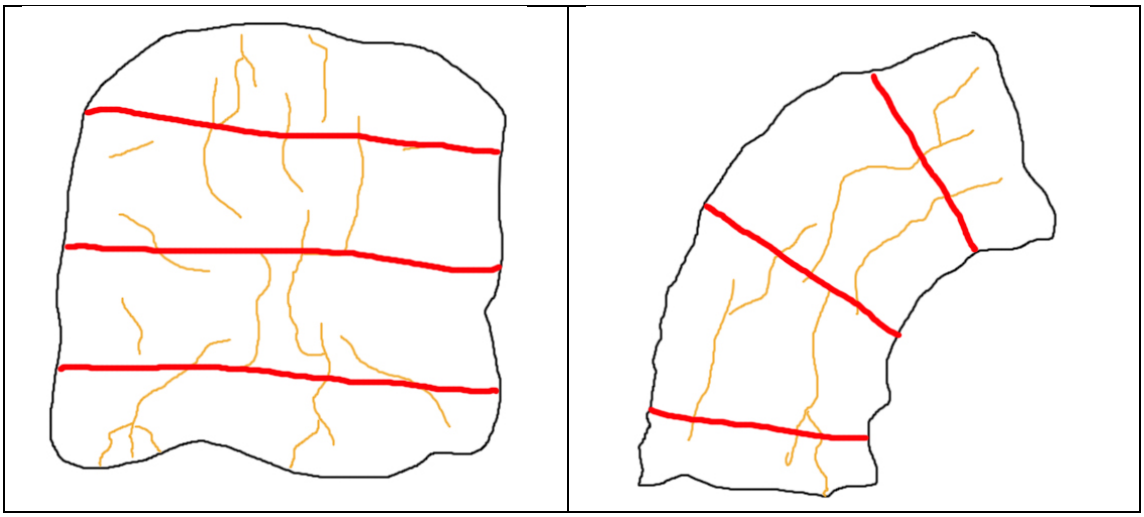


Figure XX 3. Diagrams illustrating possible transect placements based on shape and size of LTS survey area and direction of travel. Note that polygon boundaries do not need to be recorded.

Census Mapping Survey

Objectives

This survey documents the location, spatial distribution, and lineal extent of all informal trails within selected search polygons defined by the roundtable review process. Optional procedures are included for assessing trail conditions if needed. When reapplied over time, census mapping survey procedures allow managers to accurately track and characterize changes in the number, spatial distribution, and length of informal trails, and optionally, changes in their condition. Data can also be used to help decide which informal trails should be closed and to evaluate the success of management efforts to close selected trails or prevent the creation of new trails.

Guidance

Census mapping areas (CMA) are identified by the roundtable procedure. All informal trails within each CMA are inventoried as line features, with point features recorded at all intersections to aid GIS editing. Optional assessments of use type, trail width, maximum incision, vegetation cover, and bare soil (described in the Access Survey section) can be made at locations where informal trails intersect a GIS grid (e.g., 25-meter) superimposed over the CMA and downloaded for viewing during survey work on a GPS unit.

Methods

Materials

- Field manual, data/photos from prior surveys, paper data forms and pencil for backup.
- Trimble GPS, charged battery(s), antenna, stylus, appropriate data dictionary, and CMA polygons.
- Compass
- Optional: GIS grid vector file downloaded to GPS unit.
- Telescopic antenna or presentation pointer (extending to 4 ft).
- Tape measure, 6 ft.
- Geotag-enabled digital camera that links with Trimble GPS position data (preferred). Option: use a standard digital camera, set it's time date/time to match the Trimble unit, and use a software program that matches date/time stamps to record location data to the photo file (geotagging).
- Logbook

Field Procedures: Begin by exploring the previously defined CMA area to get a sense of its size and location, and presence of informal trails. Reassess the boundaries of the search polygon developed by the roundtable process and record point and/or polygon features and descriptive notes if needed to document alterations based on local topography, existing trails, or possible additional areas where trails could develop.

- Open TerraSync on the GPS and select the Data screen to create a new rover file. Select the CMA data dictionary from the pick list.
- Select the Map screen and open the Layers dialog. Select "Background Files...," locate the appropriate CMA mapping area polygon layer and designate it as the background layer. Conduct all mapping efforts in the field within this polygon, making note for later revision if the boundary polygon needs to be modified based on the field visit.
- Select the Setup screen, and open the Logging Settings dialog. Ensure logging intervals for all features in the data dictionary are set to 1 second and are based on time, not distance. Logging velocity is unnecessary, set H-Star logging to Auto, and set Allow Position Update to Confirm.
- Beginning in one corner of the CMA polygon, record each informal trail segment as an "IT_Segment". Include all informal trails, including "Trace" trails as defined in the Access Survey. Note that trail segments must be at least 20 ft in length, and that mapping should cease for gaps of more than 20 ft. Change from Trace to Trail if tread boundaries become sufficiently pronounced to assess tread width and other condition characteristics. If the CMA has a dense network of interconnected trails if may be helpful to carry some flagging or wire pine flags to place at intersections to denote which trails have been mapped.
- Ensure that the GPS records points as you move along each trail segment, every time the unit beeps and updates the point count, it has placed a node along the line you are collecting with the GPS. You are collecting a trail and need to make sure you collect points along it that adequately capture the location and shape of the trail. Watch the background file showing the CMA boundaries and stop assessing all trails at the study area boundary. To promote efficiency in post-hoc data cleanup, pause data collection in the Data or Map screens when standing still. This prevents the unit from collecting a cloud of points when it is not moving.
- At intersections with other informal trails, nest an "IT_Junction" to improve mapping accuracy in GIS data editing. Use the Options menu in the Data screen and select "Nest," then select the "IT_Junction" point feature. While the point is averaging positions, record the number of trail segments meeting at this junction. For example, a "T-intersection" has three connecting segments. Once the minimum number of positions have been collected for the "IT_Junction", close the feature, and continue mapping by unpausing/resuming data collection on the GPS.
- Resource Condition Photos: Periodically take digital photos of representative trails that are being mapped, including examples of primary, secondary, and trace trails. Record "CMA Photo Point" at each point, attribute with camera photo numbers, and azimuth of image. These photos can be examined to document the general conditions and attributes of the mapped trails. Photos could also be replicated during subsequent surveys for comparing changes in resource conditions (e.g., width, depth, substrates, muddiness).
- Continue mapping until all informal trails within the CMA boundaries have been walked and recorded.
- Resource Condition Comments: At the conclusion of mapping work for each separate area, prepare a written summary that qualitatively describes the area and resource conditions along the trails. Focus your comments on the relative proportion of trails that are obvious and distinct vs. faint and inconsistent and on proportions that are primarily derived from human use vs. wildlife use. Also note the number of occurrences of "problem" sections due to excessive muddiness or rutting that may contribute to trail proliferation and tread widening.

Point Sampling Survey

Objectives

This survey provides more accurate quantitative assessments for a variety of trail condition indicators on selected formal or informal trails whose alignments are relatively static.

Guidance

Managers in the round-table process can identify selected informal or formal trails for which more accurate data are required, perhaps to evaluate their condition in relation to standards of quality or evaluate the efficacy of management actions. Prior to fieldwork, managers must define the beginning and endpoints of each trail segment to be assessed, the point sampling interval (e.g., 200 or 300 ft), and run the point-selecting VB script (Points on Poly) incorporating a random start. The selected sample points are then downloaded to a GPS device and field staff will navigate to these same sample points during each monitoring assessment to assess tread conditions.

Methods

Materials

- Field manual, data/photos from prior surveys, paper data forms and pencil for backup.
- Trimble GPS, charged battery(s), antenna, stylus, appropriate data dictionary.
- Tape measure, 6 ft.
- Clinometer
- Compass
- Telescopic antenna or presentation pointer (extending to 4 ft).
- Geotag-enabled digital camera that links with Trimble GPS position data (preferred). Option: use a standard digital camera, set it's time date/time to match the Trimble unit, and use a software program that matches date/time stamps to record location data to the photo file (geotagging).

Field Procedures:

- Open TerraSync on the GPS and select the Data screen to create a new rover file. Select the point sampling data dictionary from the pick list.
- Select the Map screen and open the Layers dialog. Select the Setup screen, and open the Logging Settings dialog. Ensure logging intervals for all features in the data dictionary are set to 1 second and are based on time, not distance. Logging velocity is unnecessary, set H-Star logging to Auto, and set Allow Position Update to Confirm.
- Start a line feature to map the trail you are assessing. Navigate to the first trail sample point, if it is located off-trail then move to the closest point on the trail perpendicular to the point location . *Rejection of a sample point:* During the first survey, there may be rare occasions

when you need to reject a sample point due to the presence of uncharacteristic settings, like trail intersections, stream-crossings, and other odd uncommon situations. The data collected at sample points should be roughly "representative" of the adjacent sections of trail on either side of the sample point. Use your judgment but be conservative when deciding to relocate a sample point. The point should be relocated by moving forward along the trail an additional 30 ft to remove the bias of subjectively selecting a point.

- At each sample point, collect a "PS_Point" with the GPS and enter the indicator assessment data and photo numbers associated with that point. Assess the seven indicators included in the optional Access Survey protocols (see also guidance in Figure XX 2) and the additional indicators included below.

8) *Secondary Treads (ST):* Count the number of trails (excluding the sampled trail), regardless of their length, that closely parallel the sampled trails at the sample point. These are trails that split from and return to the sampled trail, remaining within 10 feet.

9) *Trail Grade (TG):* Two field staff should position themselves on the trail 5 ft either side of the transect. A clinometer is used to determine the grade (% slope) by sighting and aligning the horizontal line inside the clinometer with a spot on the opposite person at the same height as the first person's eyes. Note the percent grade (right-side scale in clinometer viewfinder) and record (indicate units used). Note: if conducted by one person then place clinometer on a clipboard with the window facing you. Orient the clipboard to be parallel to the trail grade and record <u>degrees</u> off the visible scale in the window. Be sure to note the units (degrees) and convert the data to percent slope = [tan (degrees)] x 100 after field work.

10) *Trail Slope Alignment Angle (TSA):* Assess the trail's alignment angle to the prevailing land-form in the vicinity of the sample point. Position yourself about 5 ft downhill along the trail from the transect and sight a compass along the trail to a point about 5ft past the transect; record the compass azimuth (0-360, not corrected for declination) on the left side of the column. Next face directly upslope (i.e., the fall line where water would flow downhill from a point 15-20 ft away to your feet), take and record another compass azimuth - this is the aspect of the local landform. The trail's slope alignment angle ($<90^0$) is computed by subtracting the smaller from the larger azimuth (done after data entry). Note, if water would flow down to the transect from both sides and there is nothing lower than the trail (i.e., water would drain down the tread), then record the same azimuth measure. If water would flow down to a lower area next to the trail then the trail at that point is still assessed as side-hill.

11) *Digital Photographs:* Take a photo of the transect from directly above, looking down and including the transect endpoints. This photo will help confirm, explain, or illustrate the transect substrate classes or to verify field estimates and allow assessments if there is missing data. Also take an oblique photo standing 5-10 feet away from the transect that captures the entire transect and preferably some distinctive background features. This photo will help in relocating the transect in the future once the GPS units gets field staff within a few meters. Check both photos for quality and retake if they have poor exposures or focus. Record these photo numbers in the GPS unit so they can be georeferenced.

- Collect all equipment and move on to the next sample point.

Route Finding Experience Survey

Objectives

This survey is used to inventory the hiker's Route Finding Experience (RFE) as they move through backcountry travel corridors identified by the roundtable. Data is used to inform and direct future monitoring decisions (e.g., data showing that it is easy to travel through an area on trails might suggest the need for LTS or CMA mapping.)

Guidance

Survey is to be performed by backcountry staff and visitors who are given Garmin GPS units. A timer will signal data collection every 15 minutes. The data collector may also collect a data point whenever they feel their RFE has changed "level".

Methods

Materials Needed

- RFE instructions sheet
- Garmin GPS with spare batteries
- Timer (watch/snooze alarm or repeating countdown timer)

Field Procedures: Data collector embarks on a backcountry trip, starting the repeating timer to alarm every 15 minutes.

- The Garmin GPS is turned on and a track log is initiated.
- When the alarm sounds it is reset and begins counting down again. When each alarm sounds, the data collector creates a waypoint and appends their RFE code (Class R1 - R4, see descriptions below) on the end. (WP # - R#). Optional: Enter the WP # into a notebook to add descriptive comments, include survey date.
- In addition to the time interval waypoints, the collector should stop and record a RFE Waypoint whenever they feel their RFE has changed. The collector can switch to a longer time interval (1/2 hour to 1 hour suggested) when they feel they have moved into a consistent RFE area. They should still collect waypoints when they feel RFE has changed in addition to the longer time interval waypoints.
- Upon completion, field staff should prepare a written account of additional trip information, additional reflections on the trip, the spatial distribution of use impacts, and suggestions for future RTE surveys.

RFE Class Descriptions

Class R1 - I am spending more time off trails than on trails. It is difficult to piece together trails or routes that take me in the direction I want to travel and bushwhacking or route selection through challenging pristine terrain is often required.

Class R2 - I am walking on a trail most of the time, but I have to remain alert and make frequent choices about which trails to follow. Occasional short trail gaps may exist and periodic backtracking and/or bushwhacking are required.

Class R3 - I am generally always on a trail, and can easily navigate along trails in the direction I want to travel.

Class R4 - Trails are not needed to navigate through this area.

Appendix 2: Trail Monitoring Work Flow

This Appendix contains information to assist field staff in the collection of field data, specifically the pre-fieldwork set-up tasks and the post-fieldwork data processing tasks.

Data Dictionaries

Access.ddf
Line Transect Sampling.ddf
Census Mapping.ddf
Point Sampling.ddf

Pre-fieldwork Setup Tasks

1. Load necessary data dictionary(s) sample region and background data sets onto the Trimble GPS(s).
2. Ensure that batteries are charged and ancillary equipment is ready for use:
    a. External batteries,
    b. Antennas and leads,
    c. Backpack antenna mount,
    d. Clinometer, digital camera, and measurement tools as required by sampling protocol to be implemented,
    e. Logbook and forms as needed.
3. Create and print schematic/directions to get to sampling area (if needed).

Field Tasks

1. Navigate to the sampling location(s).
2. Implement required sampling protocols(s).
3. Fill in logbook indicating work completed, dates, and field staff names.
4. Return equipment to office with completed logbook and written summaries.

Data Post-Processing Tasks

This guidance provides an outline for post-processing GPS data and implementing an organized and easily transferable/updateable spatial database. Post-processing and creation/integration of spatial datasets should be done by a single person, preferably by a GIS staff member. When transferring the data to the GIS staff, field staff should include a brief narrative describing the GPS data. This narrative should include:

- Date(s) of collection
- Field staff names and contact information
- Type of survey(s) collected

- Area of collection
- Additional comments or notes that may be pertinent

Suggested Protocols

Use Trimble's Pathfinder Office software to post-process data (differentially correct, edit and convert to ESRI shapefiles). Staff should be careful to not create redundant datasets, and to name files using a system that allows for integration into existing park datasets.

- Always work in one Pathfinder Office Project (do not create a new project each time you correct data)
- Download data from GPS devices.
- Verify the contents vs. logbook and note any discrepancies (contact field staff to resolve).
- Differentially correct GPS data.
- Name Files appropriately and/or maintain a spreadsheet with a key to interpret default GPS rover/pathfinder file names.
- Export data to ESRI shapefile using a template that creates shapefiles with desired attributes and coordinate system. Clean up and recode attribute data, enter paper form data as needed.
- Integrate Shapefiles into existing ArcMAP Spatial Databases
- Use standardized file naming conventions with file storage in separate project folders and maintain appropriate back-up and archiving of datasets.

Monitoring Tasks

1. Create summary data (maps, tables, photo compilations).
2. Prepare comparisons between zones/areas of interest and across time
    a. Calculate % and absolute change/difference,
    b. Prepare maps to facilitate visual comparison of spatial data.
3. Update monitoring/sampling plans/zones:
    a. Based on datasets coming in and comparisons to other times and/or locations,
    b. Based on input from field staff, rangers, etc.

Route Finding Experience (RFE) Tasks

1. Coordinate sampling efforts/training with field staff:
    a. Provide written RFE/Garmin user instructions,
    b. Develop sampling schedule/plan,
    c. Distribute and collect Garmin GPS units from backcountry office.
2. Download and convert Garmin Data to GIS data (use MN DNR software).
3. Integrate field notes and attribute RFE point data as needed.
4. Prepare summary maps:
    a. Interpolate surface from data if sufficient points exist,

   b. Color code point data for visual comparison of RFE data,
   c. Calculate distance to nearest trail/road/access point,
   d. Summarize distance(s) to RFE points by RFE class.
5. Maintain an appropriate back-up of datasets using appropriate naming conventions.
6. Integrate RFE data with IT spatial datasets (from other protocols above):
   a. Spatially analyze RFE data relative to IT networks and other infrastructure.
   b. Compare data sets at differing times and varied locations within management area.

Appendix 3: Glossary

Containment strategy – **A** visitor use management method that optimizes visitation by accepting controlled degradation of resources through development of formal facilities; and informal hardening of sites at areas of concentrated use. This management strategy allows for less emphasis on education and accommodates lower levels of personal stewardship behaviors to retain desired conditions.

Desired conditions **–** The physical, biological, or experiential qualities determined by managers to be important for the perpetuation, enhancement, or restoration of resources and values**.**

Dispersal strategy **– A** visitor use management method, with an essential educational emphasis, applicable in low-use areas only. This management strategy optimizes preservation of natural landscape characteristics and depends upon personal stewardship behaviors in lieu of facility development to retain desired conditions.

Formal trails – Intentionally planned and developed trails established to provide recreational access to roadless areas and to protect resources by concentrating visitor traffic on resistant tread surfaces to avoid trail braiding, erosion, etc., or to minimize threats to natural conditions (spread of invasive species, disturbance of sensitive habitats, etc.) (Monz et al. 2009).

Impacted – Recreation managers denote any area with undesirable visitor-related change in resources that would likely, if managed for recovery, return to natural condition within a defined, short-term period as *impacted*. The standard recovery time for this classification is one year, or one season cycle (Lawhon 2010) [not to be confused with *Impaired*].

Impaired – Recreation ecologists classify areas with undesirable visitor-related changes in resources that would likely, if managed for recovery, not return to natural condition until decades have passed, as *impaired* (J. L. Marion, Unit Leader of Virginia Tech Field Station, Patuxent Wildlife Research Center, USGS, pers. comm.) [Not to be confused with *Impacted*].

Informal trails – Visitor-created trails that can contribute substantially greater impacts to protected area resources than formal trails (Monz et al. 2009) (see *Formal trails*).

Trace – A nascent visitor-caused linear impact that is an emergent informal trail segment adjacent to commonly-used access areas, attractions, informal trails, or formal facilities.

Natural condition – A landscape exhibits natural condition to the degree it remains undeveloped, substantially free from the effects of modern civilization, dominated by natural processes, and is perceived by the average visitor as "natural."

Visual resource management – Many public lands contain outstanding scenic landscapes. Visual resource management is a system for minimizing the visual impacts of surface-disturbing activities and maintaining scenic values for the future. The system involves inventorying scenic values, and then evaluating proposed activities to determine whether they conform with

management objectives for the scenic values. Management objectives for scenic values are usually included in an agency planning document, such as a visitor use management plan.

Wilderness— As a land designation, "*W"ilderness* refers to lands and waters designated by Congress as a component of the National Wilderness Preservation System. In such cases, the word is capitalized. When used as a descriptive adjective, "*w"ilderness* refers to natural qualities or experiential values commonly associated with designated Wilderness *as well as* other undeveloped wildland such as Minimal Management areas.

Wilderness character – Wilderness character embodies both tangible and intangible dimensions. It is a combination of biophysical conditions, experiential opportunities, and symbolic meanings that distinguish designated Wilderness from other lands. An area possesses Wilderness character to the degree that: 1) it retains untrammeled, natural, and undeveloped conditions; 2) provides opportunities for solitude or primitive and unconfined recreation and 3) its stewardship upholds the notions of respect, restraint, humility, and obligation in our relationship with the land. Protection of Wilderness character is the primary criteria for judging the appropriateness of proposed actions in designated Wilderness.

Wilderness characteristics – Qualities commonly associated with designated Wilderness and other types of wildland such as Minimal Management areas. These include biophysical elements (e.g., undeveloped conditions, natural appearances, free-functioning ecosystems, native flora and fauna), and conditions conducive to experiential opportunities (e.g., solitude, natural quiet, adventure, primitive and unconfined recreation).

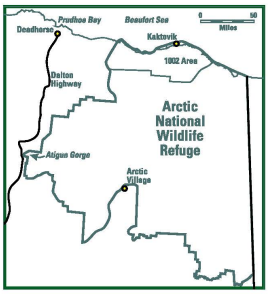
Appendix 4: Arctic Refuge Outreach materials for Minimizing Visitor Impacts

Day Hiking in Atigun Gorge located on the web at http://arctic.fws.gov/pdf/atigun.pdf

U.S. Fish & Wildlife Service

Day Hiking in Atigun Gorge

Practice restraint in this wild landscape



Situated close to the Dalton Highway, Atigun Gorge is a popular destination within the Arctic National Wildlife Refuge. Although the Refuge is vast, this popular hiking area is fragile and easily impacted by human activities.

Be a steward of the land. Visit wisely and gently to preserve the gorge for future visitors and the wild creatures who make it their home.

Atigun Gorge—midnight at the summer solstice.
USFWS / Dave Lokken

Atigun Gorge is special:

Important for wildlife: Have you ever wondered why the Arctic Refuge boundary jogs westward to include Atigun Gorge? Congress included Atigun Gorge within the Refuge because of the gorge's significant value to Dall sheep as a wintering range, lambing area, and source of mineral licks. The gorge is important to other wildlife, such as bears and caribou, as a travel corridor and feeding area. It also provides nesting habitat for birds.

Significant for research: Scientists conduct a variety of projects in Atigun Gorge. Study plots may be marked. Please leave the marked areas as you find them.

Offers visitors an unusual opportunity: What does it mean that the Arctic Refuge has no designated hiking trails? It means that visitors have the freedom to respond to the landscape as it unfolds before them, unlike in places where heavy human use forces managers to restrict visitors to designated trails. Hiking on trails may be recommended in other areas, but here it is worth the effort to seek your own route, which will disperse use and help heal emerging paths in Atigun Gorge.

Vulnerable to human use: Atigun Gorge receives concentrated visitation because it is one of the few locations within the Arctic Refuge that is easily accessible from the road system. In addition, the area's topography funnels use into the gorge. Thank you for caring for this area by following the guidelines at the right to limit your impact on the Refuge.

Protect the land:

Reduce impacts to Atigun Gorge. Avoid causing physical changes to vegetation or rocky surfaces. Trails form quickly in the arctic, scarring the land. Healing, if it occurs at all, can take years.

- **Prevent the creation of trails and worn areas by dispersing use.** Don't step where others have stepped before. Choose shoes with low-tread soles. If you visit multiple times, alternate your destinations or explore new routes. Consider traveling in small groups (commercial guides limit group size to 7 hikers). Minimize damage to vegetation by resting on rock, gravel, sand or snow.
- **Leave no sign of your visit.** Please pack out your trash and any that you find; leave your route unmarked; and leave natural objects and items of antiquity for others to discover.
- **Deal properly with human waste.** Urinate at least 200 feet (about 70 paces) from flowing water. Carry human waste storage bags, such as "WAG BAGs," if you plan to pack out your solid waste; or bring a trowel to bury such waste at least 200 feet from flowing water. Pack out toilet paper.

Respect wildlife:

National Wildlife Refuges are places where wildlife comes first. Wild creatures need a safe place to find food and raise their young. You are a visitor in their home.

- **Give wildlife the right-of-way and avoid those with young.** Animals may respond to repeated disturbance by abandoning their feeding areas, nesting sites, and even their young. If an animal alters its behavior because of your presence, you are too close. Use binoculars and telephoto lenses to observe and photograph wildlife.
- **In brushy areas, let bears know where you are.** Talk or sing so that animals are not startled by your presence.
- **Keep food and trash secure from bears and other animals.** Never leave food unattended. Bears that obtain human food may become aggressive toward visitors and may need to be destroyed. If you leave your daypack unattended, store food and trash in a bear-resistant container.

Arctic National Wildlife Refuge
101 12th Avenue, Room 236
Fairbanks, AK 99701
voice: 907-456-0250 toll free: 800-362-4546
http://arctic.fws.gov/

AMERICA'S NATIONAL WILDLIFE REFUGE SYSTEM...
Conserving the Nature of America

Strategies for Minimizing Your Impacts located on the web at http://arctic.fws.gov/camping.htm

U.S. Fish & Wildlife Service

Arctic
National Wildlife Refuge

Strategies for Minimizing Your Impacts

The Arctic National Wildlife Refuge, in the far northeast corner of Alaska, remains much as it has for thousands of years. Its austere beauty is driven by untamed forces of nature that continue to this day.

These lands, and the plants and animals that live here, evolved knowing only the light step of occasional nomadic hunters. Today, many more people come than in the past. This vast and remote wilderness is a place of great power, but it is exceptionally fragile and can be damaged.

Whether your plans include hunting, hiking, or other activities, you have something in common with all Refuge visitors. Your experiences will be intertwined with the wildlife and habitats the Refuge is meant to preserve, and your practices will influence the future well-being of this place.

Presented here are a set of principles and strategies you can use to minimize impacts during your time within the Arctic Refuge—actions you can take so that signs of your presence will disappear within a year. These strategies will ensure this awe-inspiring, wild place remains unblemished for future generations.

Those who are here now, and those who will come in the future, hope that you make a personal commitment to minimize signs of your presence within this magnificent but demanding wilderness.

Plan ahead:

You will best be able to limit your impacts on the Refuge if you prepare wisely and thus avoid unanticipated actions that could result in resource damage. Pack the necessary clothing and equipment that will keep you warm, safe, and well-fed. Leave your itinerary with family or friends.

- **Design your route** to accommodate the skill level and physical ability of each member within your group. Remember that foot travel in the Refuge is often slow-going over unstable terrain. Hiking a specific distance here may take two to four times as long as it does on groomed trails elsewhere.
- **Plan to be completely self-sufficient.** Cell phones do not have coverage across the Refuge, and satellite phones may not work in mountainous terrain or harsh weather conditions.
- **Reduce packaging** to limit trash. When original packaging is excessive, many people repackage their dry food into plastic zip bags.

Respect Solitude:

In contrast to the every-day stresses of modern living, the Refuge is an ideal destination for the many visitors seeking solitude and restoration. Although the Refuge is vast and remote, certain areas tend to receive a lot of public use—such as aircraft access points. If solitude is your primary concern, you may wish to arrange your trip to avoid times and locations of high use.

- Be sensitive to other visitors' potential desires for solitude by **minimizing disruptive noises and being aware of your effects on others.**

Limit Group Size:

Large groups may leave especially noticeable and lasting impacts on Arctic landscapes. Refuge employees and research project leaders limit their groups to the fewest necessary participants. Commercial guides are required to limit their group size. We encourage private users to do the same.

- The recommended **maximum group size is 7 for land travelers.**
- The recommended **maximum group size is 10 for water travelers.**

Naturalize Camp Sites:

Rocks in the outline of a tent or fire ring; wood gathered into an ordered pile; crushed vegetation—these are some visible signs that campers have been to a site. We suggest the following practices to limit signs of your presence on the landscape.

- **Naturalize the site when you leave** (undo site changes by repositioning rocks, logs, etc. to their original locations; wiping out footprints in the sand; and dispersing fire ash; etc.).
- Choose **shoes with low-tread soles** to avoid trail formation and vegetation wear throughout your camping area.

Protect Vegetation:

A few areas of the Refuge receive concentrated use, resulting in trail formation and trampled vegetation. Consider taking the following measures to limit further deterioration and allow impacted areas to heal.

- **Camp and walk on durable surfaces** (rock, gravel, sand, snow, annually-flooded riverbar, etc.) or on sturdy vegetation when these are available.
- **Disperse use when in pristine areas**. For example, when walking in a group, spread out in a fan pattern to help prevent trail formation, and when camping, relocate if signs of wear begin to appear.
- **Avoid worn areas to allow their recovery.** If you can tell that someone has placed a tent there before, or if a faint path is emerging in the vegetation, choose another location. An exception is at aircraft landing sites where practical alternatives do not exist. Here it may be wisest to use existing camp sites and trails to keep impacts from spreading.

Dispose of Human Waste:

Human waste and toilet products are visible at some high-use locations within the Refuge. Moist towelettes and wipes are particularly persistent in the north. Out of courtesy to others, we recommend the following tactics.

- **Pack out toilet paper, towelettes, and sanitary products, or burn them completely to ash**. Never bury these items. If buried, animals and seasonal thawing will unearth them, and some take years to deteriorate in arctic conditions.
- Human waste should be **buried 6 to 8 inches deep, at least 200 feet away** from camps, trails and waterways. Many visitors pack a light-weight trowel to dig these "cat-holes."
- **Consider carrying out your human waste** from high-use areas where it is accumulating.

Remove Trash:

Bits of plastic, crushed cans, and tangles of fishing line don't belong in the Refuge.

- **Pack out all trash, or burn it completely** to powdery, white ash and pack out any remaining unburned pieces (foil, etc.).

Reduce Fire Impacts:

Fires, though allowed, are not recommended within the Refuge because trees grow very slowly in the far north, and wood is scarce in some areas. Visitors who have campfires should take special care to ensure that their fires do not leave visible scars on the land.

- Use of **white gas or similar fuel for heating and cooking** is encouraged.
- If you feel the need for a campfire, **burn limited amounts of dead, downed wood** in ways that will not cause lasting impacts (use fire pans or blankets, mound fires, etc.).
- **Remove evidence of your campfire** by burning wood completely to powdery, white ash, and by dispersing the collected materials and ash when cold.

Protect Wildlife:

Observing wildlife in their natural setting is one of the most rewarding aspects of a Refuge experience, but if their behavior is changed by your presence you are too close. An animal that associates humans with food rewards may become tolerant of people, become a nuisance, or have to be destroyed.

- **Keep food away from wildlife.** Reduce the chances of dangerous encounters by not allowing food scraps or food odors to attract wildlife. We encourage you to disperse dishwashing water away from camp, and to use approved bear-resistant containers to store food and trash.
- **View animals from a distance** using a spotting scope, binoculars, or camera with telephoto lens, etc.

Preserve the Landscape:

Whether observed close at hand or viewed as broad vistas, the landscapes of the Refuge present spectacular sights of sublime beauty. It is an easy courtesy to others to limit the sights and sounds of your presence, and to leave things as you find them, for others to discover for themselves.

- **Minimize visual impacts** to others by using equipment and gear of muted colors. (Contrasting colors may be necessary for safety in certain circumstances.)
- **Leave natural objects and private property undisturbed.**

Those coming to the Refuge hope to see it undisturbed and full of natural beauty. We all share responsibility to preserve this wild place—the responsibility to have a limited impact on the land and to protect the intricate web of life it supports—so that those in the future may be renewed and inspired in their turn by this majestic wilderness.

Thank you for your efforts to limit your impacts on the Arctic Refuge.

David Prentiss

The National Wildlife Refuge System conserves fish, wildlife, and their habitats for all Americans. This network of lands provides opportunities for wildlife-dependent activities including hunting, fishing, wildlife photography, and wildlife observation.

The Arctic Refuge was established to protect wildlife, wilderness and recreational values, to ensure adequate water quality and quantity, and to provide continued subsistence opportunities to local residents.

Arctic National Wildlife Refuge
907/456 0250 800/362 4546
arctic_refuge@fws.gov
http://arctic.fws.gov/

AMERICA'S NATIONAL WILDLIFE REFUGE SYSTEM...
Conserving the Nature of America