BACKCOUNTRY CAMPSITES AT WAPTUS LAKE, ALPINE LAKES WILDERNESS, WASHINGTON: CHANGES IN SPATIAL DISTRIBUTION, IMPACTED AREAS, AND USE OVER TIME

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by

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ABSTRACT

BACKCOUNTRY CAMPSITES AT WAPTUS LAKE, ALPINE LAKES WILDERNESS, WASHINGTON: CHANGES IN SPATIAL DISTRIBUTION, IMPACTED AREAS, AND USE OVER TIME

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The Wilderness Act was created to protect backcountry resources, however; the cumulative effects of recreational impacts are adversely affecting the biophysical resource elements. Waptus Lake is located in the Alpine Lakes Wilderness, the most heavily used wilderness in Washington State. Waptus Lake campsites were assessed for spatial patterns, biophysical conditions, and use trends in order to provide long-term management recommendations. Individual campsite areas were considerably larger than management standards allow, averaging six times the 37.2 m^2 maximum, and most were out of compliance with setbacks from water and trails. Impact assessments revealed that 34% of the campsites were rated as “severe”; however, overall impacts improved significantly between 1985 and 2008. Hiker and packstock levels have decreased between the 1996-2008 period, and packstock setbacks from the lake have been implemented, aiding in overall recovery. Wilderness land managers must address compliance issues in a proactive manner; balancing policy and feasible restoration methods.

ACKNOWLEDGEMENTS

On July 5th 2003, my friend John Morrow – wilderness ranger for the USFS Cle Elum District – convinced me to haul myself and a ridiculous amount of gear up a mountainside to check out this place called the Alpine Lakes Wilderness. That trip sparked a passion for wild places and set me on a course of interest that led to this project. Thank you John. I hope this endeavor inspires tangible protection of the landscapes you love. Thank you to Lisa Therrell, Troy Hall, Jon Herman, and especially David Cole for their ongoing research efforts that helped guide and inspire this project. Your work has likely protected the integrity of immeasurable amounts of wilderness for future generations to experience.

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CHAPTER I

INTRODUCTION

The Wilderness Act of 1964 was enacted to protect unique ecological systems and provide a place for exploration and contemplation in the spirit of self-reliance and adventure. The Act (Section 2c) defines wilderness as the following:

> A wilderness, in contrast with those areas where man and his own works dominate the landscape, is hereby recognized as an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain. An area of wilderness is further defined to mean in this Act an area of undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions and which (1) generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable; (2) has outstanding opportunities for solitude or a primitive and unconfined type of recreation; (3) has at least five thousand acres of land or is of sufficient size as to make practicable its preservation and use in an unimpaired condition; and (4) may also contain ecological, geological, or other features of scientific, educational, scenic, or historical value.

By way of setting aside these protected lands, the Act also protects biological refuges which are important to scientific research and serve as baseline data to compare and contrast with more developed urban areas. The symbolic intent of wilderness was summarized by President Lyndon B. Johnson (NPS, 2007), upon signing the Wilderness Act of 1964:

> If future generations are to remember us with gratitude rather than contempt, we must leave them something more than the miracles of technology. We must leave them a glimpse of the world as it was in the beginning, not just after we got through with it.

Research Problem

The Wilderness Act recognizes the value of protecting ecological systems, opportunities for scientific inquiry, and recreational experiences; however, these primary objectives lead to conflicting goals: the provision of opportunities for use, preservation of natural or pristine conditions, and avoidance of intentional ecological manipulation (Cole, 1995). These conflicting goals dovetail to create a paradoxical situation: i.e., wilderness is protected, in part, to provide recreational and contemplative opportunities in a pristine natural refuge; however, the cumulative impact of recreation on natural systems transforms the landscape in a manner that may take decades or centuries to restore (Cole & Spildie, 2007). Recreation-induced landscape degradation requires active human intervention and ecological manipulation in order to maintain “pristine conditions” (Cole, 1995). Ironically, intentional human intervention through ecological manipulation is in direct conflict with the language presented in the Wilderness Act.

Recreation impacts numerous wilderness resource elements including soil, vegetation, wildlife, and water. Visitors cause unintentional biophysical environmental degradation including decreased density and composition of vegetation and organic soil horizons, followed by soil compaction and erosion (Cole, 2007). Other potential impacts include compaction-related soil chemistry changes, reduced levels of solitude, and arguably, degradation of the overall “wilderness experience” described by the Wilderness Act as necessary to allow users to experience true naturalness, primitiveness, wildness, and remoteness (Landres et al., 2005). Trails and campsites are considered necessary to provide opportunities for wilderness recreational experiences but these systems, designed to maintain public use, cause significant environmental impact. Evidence for this damage includes the proliferation of user-created social trails and associated campsites that substantially increase the overall area affected by backcountry camping (Cole, 2007). Additional signs of unacceptable environmental degradation are intentional, such as vandalism to trees, rocks, and other natural wilderness features.

In order to identify when and where environmental degradation is reaching unacceptable levels in a timeframe that allows for corrective action, it is essential to collect environmental impact baseline data and conduct periodic surveys to detect major changes in campsite conditions (Cole, 2007). Along with impact data, managers need reliable information about overall visitor use trends. Both short-term and long-term management decisions must be based on empirical studies documenting current levels of human use and changes in resource conditions over time (Watson, Cole, Turner, & Reynolds, 2000). Without baseline data, land managers have limited information about site-specific impact changes over time and are forced to make judgment or “best guess” decisions (Watson et al., 2000). Additionally, this data gap makes it difficult to create management objectives in response to impacts and to justify the costs associated with active intervention methods.

The Alpine Lakes Wilderness (ALW), added to the National Wilderness Preservation System in 1976, is the most highly used wilderness area in Washington. The wilderness area, co-managed by the Mt. Baker-Snoqualmie and Okanogan-Wenatchee National Forest, has experienced the effects of overuse first-hand due to its popularity and proximity to Washington’s heavily populated Puget Sound region (Cole, Watson, Hall & Spildie, 1997; Hall & Cole, 2006). Over one-half of the State's population lives within a one-hour drive of the wilderness, bringing nearly 150,000 annual visitors (USFS, Mt. Baker-Snoqualmie National Forest, 2007).

The U.S. Forest Service Alpine Lakes Area Land Management Plan (ALALMP) states that soil displacement caused by natural and anthropogenic processes will be limited to a rate that mimics natural processes (USFS, 1981). The Plan goes on to state that compaction should not exceed an acceptable level of impact or the point where it limits natural plant establishment and growth, with exceptions given to designated trails and campsites. The ALALMP regulations state that packstock must be tethered at least 200 ft (61 m) from water. The Plan further recommends that “where possible” campsites should be set back from trails, meadows, lakes, streams, and other camps by at least 200 ft (61 m). The Plan also recognizes that the loss of ground cover is to be expected at high-use destinations; however, the loss of ground cover should not exceed 400 ft^2 (122 m^2) or 1 % of any acre (USFS, 1981). In the three decades since the ALALMP was written, high rates of human and packstock use at Waptus Lake in the ALW (Figure 1) have damaged soils beyond acceptable limits (USFS, 1985). This damage has occurred within campsites and along the shores of lakes and streams, leading to decreased vegetation and increased erosion of soils. This erosion may lead to increased nutrient and sediment flow adversely affecting water quality in the lake and Waptus River. The history of high use at Waptus Lake has led to a majority of campsites exceeding an acceptable level of impact.

Research Objectives

As a step towards addressing this issue, research focused on wilderness campsites in the area around Waptus Lake in the central region of the ALW (see Figure 1).

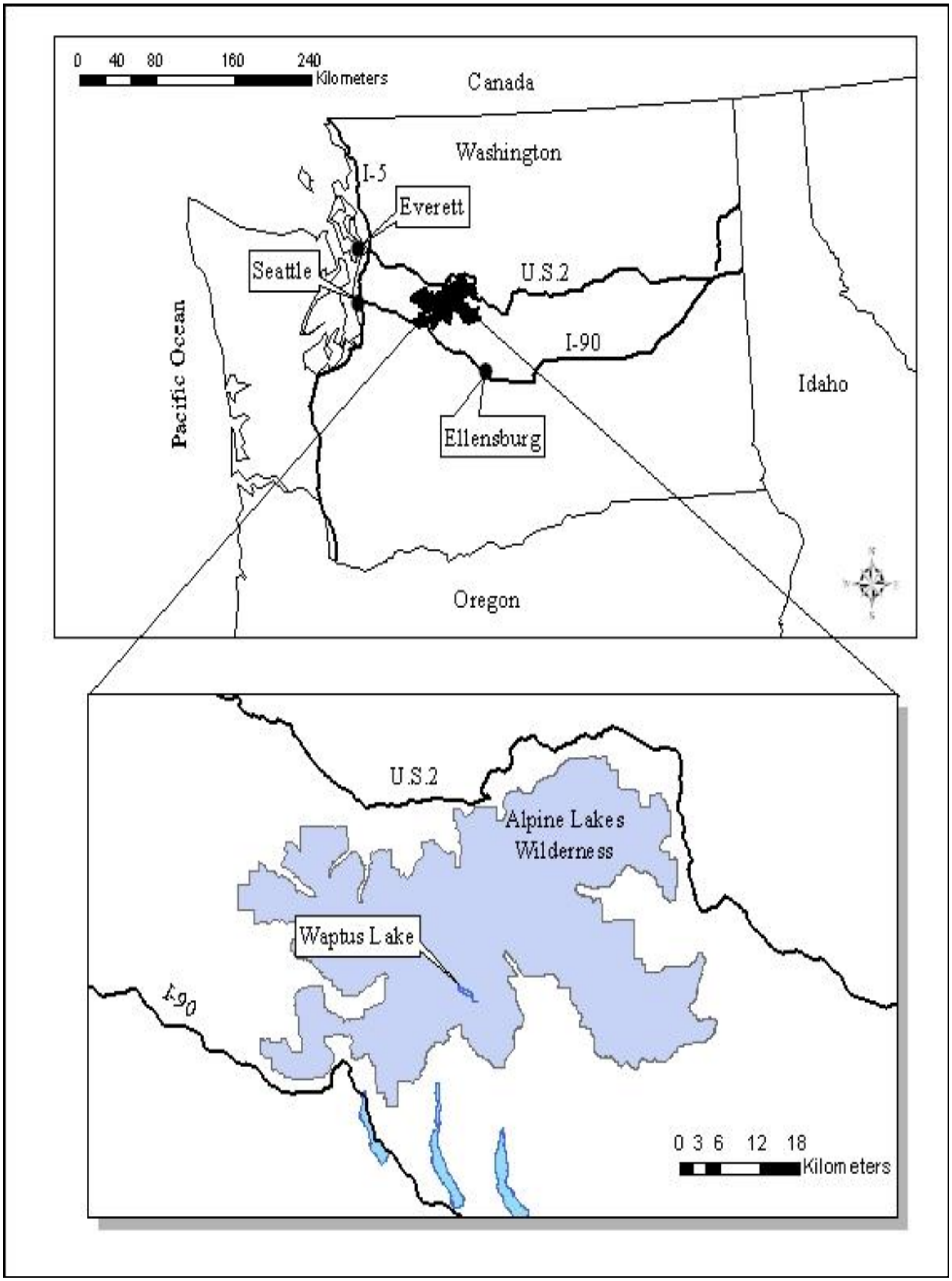

Figure 1. Alpine Lakes Wilderness Area map.

Specifically, this project: 1. documents the spatial and temporal patterns of campsites around Waptus Lake; 2. measures and compares the biophysical condition of each Waptus Lake campsite as of 2008 – 2009 with baseline data from 1985 to 1988; 3. analyzes Waptus Lake trailhead data to document backcountry use trends over time; and 4. provides long-term management and policy recommendations for Waptus Lake in light of the research results.

Significance

Waptus Lake is one of the more popular lake camping destinations in the ALW. Decades of heavy visitor use has created impacts that must be addressed. The absence of consistent campsite impact monitoring programs, reliable estimations of use trends, and proactive campsite intervention has led to rates of environmental degradation exceeding the ALALMP threshold. Waptus Lake and the ALW Area are particularly vulnerable to these threats due to their proximity to the growing Seattle metropolitan area. The consequences of increased demand and associated impacts are compounded by wilderness managers' reluctance to intervene due to a perception that marginal recovery rates fail to justify the expense of campsite intervention (Juelson, 2001). In the debate over whether wilderness restoration methods are worth the time and money associated with projects, an opportunity exists to use Waptus Lake as a restoration protocol research site and to further the study of campsite monitoring techniques to document changes of impact in response to restoration treatments. Environmental impact data along with reliable statistics of use trends will provide land managers with scientific knowledge, in addition to memory and personal experience, on which to base their management decisions.

The patterns of impact found at Waptus Lake are likely mimicked throughout the ALW and other mountain wilderness areas in the United States. To enforce the literal (Section 2c) and symbolic elements of the Wilderness Act, protected areas needs better systems for monitoring the environmental impacts in order to intervene in areas where environmental degradation has exceeded acceptable levels.

CHAPTER II

LITERATURE REVIEW

Spatial and Temporal Patterns of Wilderness Campsites

Spatial Distribution of Campsites

Campsite selection behavior in dispersed recreation settings has resulted in an uneven distribution of impacts across the wilderness landscape, with locations clustered around prime destinations such as lakes and peaks. Wilderness lakes are incredibly appealing for recreational use. Users are attracted to these areas for many reasons, including relaxation, adventure, fishing, hunting, and climbing. Peaks draw visitors for the outstanding vistas and climbing opportunities (Hammitt & Cole, 1987). Previous research conducted in the ALW found that visitors are more likely to crowd popular lakeshores, rather than travelling farther for a more secluded site with less of the experience attributes (see Table 1; Brunson, 1989, Cole & Hall, 2007).

Campsite Choice Criteria

Wilderness campers typically chose their campsites using a three-stage choice model (see Table 1). The campsite selection stages are based on “necessity attributes” such as flat ground for tents and availability of water, then evaluating sites for “experience attributes”, including views and degree of privacy, and finally considering “amenity attributes”, such as shade, fire rings, and access to toilets (Brunson, 1989). A significant amount of research has been dedicated to understanding campsite impacts, but research addressing the spatial aspects of recreational impacts has received little

Table 1

Three-stage campsite choice model

Attribute	Attribute type
Flat area for tents	Necessity
Dry and well-drained	Necessity
Sheltered from wind and rain	Necessity
Close to water	Necessity
Good view of mountains and/or lake(s)	Experience
Privacy: out of sight and sound of others	Experience
Screening from other campsites	Experience
Close to good fishing	Experience
Close to other campers	Experience
Close to trails/climbing routes	Amenity
Has limited bare ground	Amenity
Close to toilets	Amenity
Has shade	Amenity
Gets morning and/or evening sun	Amenity
Improvements (fire ring, seating)	Amenity

Source: Brunson, 1989.

attention. This knowledge gap is worth noting due to the fact that spatial decisions are made by land managers, frequently, without sound research to guide those decisions (Cole 1989b).

Effects of User Characteristics on Spatial Distribution of Campsites

The prominent type of use can dictate the spatial extent of impact. Research shows that backpacker and packstock use directly impacts wilderness vegetation (Olsen-Rutz, et al. 1996; Leung & Marion, 2000), soils, water, wildlife, and aesthetics by damaging plants, denuding and compacting soils, leaving behind wastes, and coming in contact with other wilderness visitors and wildlife (McClaran & Cole, 1993).

In regard to long-term management of recreation resource impacts, understanding the factors that influence site choice is important for redistributing use, maintaining the isolation and solitude characteristics of the wilderness, and reducing user conflicts and congestion (Lucas, 1990). Analysis of recreation impact is quantified by the intensity and spatial extent of impacts (Cole, 1994). To this end, researchers need to focus on developing methods for quantifying the spatial extent and patterns of impact to match the existing methods for quantifying the intensity of impact.

Research has shown that on a landscape scale, recreational impacts directly affect a very small proportion of land area (Hammitt & Cole, 1987). However, determination of the significance of recreation impacts based on the total proportion of land disturbed tends to underestimate the ecological and social consequences of impact. A campsite spatial distribution analysis is an essential companion tool to impact monitoring. Conducting a thorough analysis and communicating the results of that analysis to managers prior to the development of management intervention plan will help inform strategy and long term decisions.

Spatial Distribution of Packstock Impacts

The spatial distribution of packstock impact tends to be greater than the spatial distribution of backpacker impacts. For example, if two backpackers are on an overnight trip, their use is likely to impact site conditions within their campsite in the ways listed above. In comparison, if two packstock users complete the same trip, we would likely see the same impacts caused by the backpackers, plus additional impact from the packstock. This group may be comprised of a 1:1 ratio of people to packstock, or the ratio may be greater due to the need for extra animals to transport gear required for an overnight stay. In this scenario, each animal will need to be tethered in some way within or near the campsite, which increases the overall spatial distribution of impact. Research examining the response of mountain meadows to grazing in Yosemite National Park supports this theory and adds that grazing by recreational packstock, even at low intensities (a few hours per year), reduced productivity, vegetation cover, and litter cover while increasing bare soil and altering the species composition of the study areas (Cole, Van Wagtendonk, McClaran, Moore & McDougald, 2004).

Temporal and Spatial Impact Patterns

It is logical to assume that camping-induced impacts occur in a linear fashion, meaning that more visits to a particular site lead to a commensurate increase in campsite impacts. While recreational use does lead to impact, the pattern is not always linear (Hammitt & Cole, 1998). Figures 2 illustrates the temporal pattern of impact in forested settings where recreational camping impacts tend to develop immediately after first use and are extremely slow to recover, even when the site experiences low to moderate use (Cole & Monz, 2004).

A recent 3-year study analyzed the rate of impact from camping on previously undisturbed sites in a forested setting for duration of either one or four nights per year. Results indicated that the low-use sites exhibited significant signs of impact, and these impacts persisted even after three years of monitored recovery (Cole & Monz, 2004).

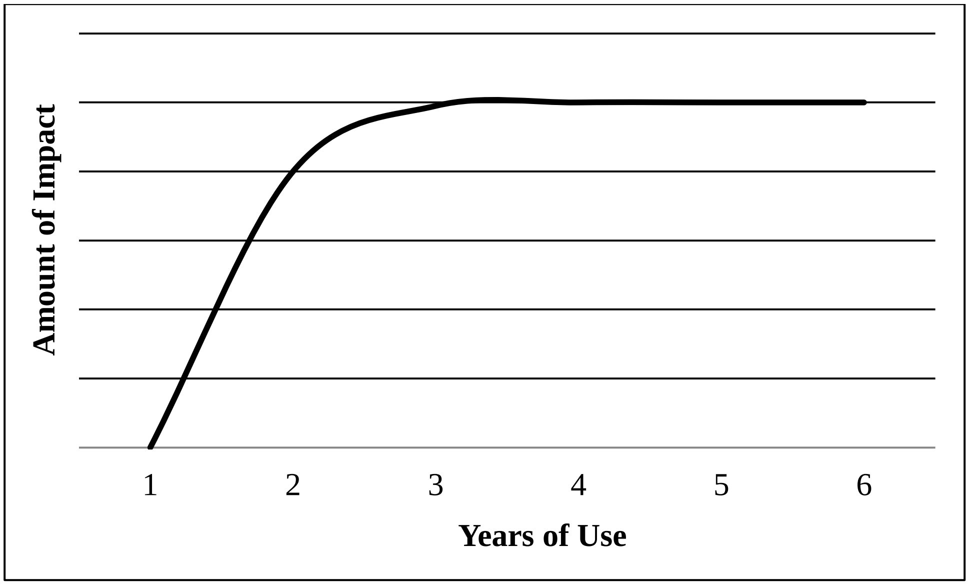

Figure 2. Temporal pattern of campsite impact. Adapted from Hammitt & Cole, 1998.

The spatial distribution of impact can increase rapidly when overcrowding occurs. For example, if three large groups decide to camp at the same destination over a long weekend, the number of visitors can easily exceed the number of established campsites, leading to the development of new campsites and causing new impacts that may persist for years. These location choices made by visitor groups lead to newly established campsites increasing the overall spatial coverage of impacted area (Lucas, 1990). This trend helps to explain the study findings of three western wilderness areas where campsite proliferation increased 53% to 123% over 16 years. The study findings indicated that resource degradation was caused by the proliferation of new sites as opposed to changes caused by the expansion of existing campsites (Cole, 1993).

Biophysical Condition of Campsites

The direct effects of recreation on soil and vegetation cause indirect effects on resource elements, such as decreased soil microbial activity, a change in the composition of vegetation, and altered microclimates. The direct and indirect impacts naturally extend to wildlife and water, which were not addressed in the scope of this project (see Table 2).

Table 2

Common Forms of Recreation Impacts in Wilderness

	Soil	Vegetation	Wildlife	Water
Direct Effects	Soil compaction	Reduced height and vigor	Habitat alteration	Introduction of exotic species
	Loss of organic litter	Loss of vegetation cover	Loss of habitats	Increased turbidity
	Loss of mineral soil	Loss of fragile species	Introduction of exotic species	Increased nutrient inputs
		Loss of trees and shrubs	Wildlife harassment	Increased pathogenic bacteria
		Tree trunk damage	Modification of wildlife behavior	Altered water quality
		Introduction of exotic species	Displacement from habitat	
Indirect Effects	Reduced soil moisture	Composition change	Reduced health and fitness	Reduced aquatic ecosystem health
	Reduced soil pore space	Altered microclimate	Reduced reproduction rates	Composition change
	Accelerated soil erosion	Accelerated soil erosion	Increased mortality	Excessive algal growth
	Altered microbial activity		Composition change	

Source: Leung & Marion, 2000

Wilderness visitors spend considerable time in campsites and wildlife respond to the disturbance either by avoiding campsites, thereby being displaced from habitat and water access or by modifying behavior and seeking campsites as they develop an unhealthy dependence on food outside their natural diet (Leung & Marion, 2000). Recreation impacts and water quality are also interrelated as trampling and depletion of the soil duff layer leads to increased runoff into lakes and streams, and packstock-related waste can lead to increased nutrient input (Leung & Marion, 2000).

Vegetation Impacts

Recreation causes the loss of vegetation through human and packstock trampling, the collection of vegetation for campfires, and through the grazing activities of recreational packstock (Cole, 1987). As campsite use occurs, a decline in vegetation usually follows (Marion & Merriam, 1985). On many recreational campsites, vegetation is almost completely gone. Once the understory vegetation has been significantly disturbed or removed, it can be very slow to recover (Cole & Monz, 2004; Cole & Spildie, 2007). Most studies documenting camping-related vegetation loss have found high levels of vegetative loss and increased bare soil exposure after only modest use. For example, Monz (1998) found that low-use campsites in Prince William Sound of Alaska lost 81-93% of their vegetation cover. Once these soils become compacted and experienced vegetation loss, recovery was a daunting task as the loss of vegetation also limited the availability of seeds and vegetative sprouts from native parent plants (Zabinski & Cole, 2000). Compounding this situation is the fact that mountain soils tend to be poorly developed and many sub-alpine plant communities establish infrequently and grow slowly (Cole & Spildie, 2007).

Soils Impacts

Like other ecological systems, soils are ever changing and dynamic. Parent material, topography, biota, climate and time all influence individual soil types and how they will respond to recreational impacts. In backcountry camping sites, changes in soil ecological systems are shaped increasingly by human activity (Suding & Gross, 2006). It is often the indirect impacts that have the most significant effects. Soil trampling is an example of an indirect impact that has major effects on soil ecological health and composition (Hammitt & Cole, 1998). These consequences are illustrated by research conducted in the Boundary Waters Canoe Area Wilderness. This study compared 48 campsites with undeveloped control sites and found that trampling led to changes in soil bulk density, organic horizon thickness, area of exposed mineral soil, and soil compaction (Marion & Merriam, 1985).

Soil Texture and Structure

Soil texture describes how individual sand, silt, and clay particles combine with into aggregates with pore space for air, water, and suspended solids (Buol, Southard, Graham, & McDaniel, 2003; Hammitt & Cole, 1998). Overall particle distribution affects bulk density, physical stability and water permeability (USDA, 2008). If results show a trend towards coarse sands, cobble, and gravel, the bulk density tends to be relatively low, providing larger packing voids and, therefore, larger pore spaces, meaning water can move and drain very rapidly through these soils (see Table 3). With an increase in fine particles, the bulk density will increase and the permeability will be reduced. Conversely, fine textured sediment provides a greater soil surface area which results in the soil holding more water, having an increased ability to store nutrients and supply them to plants, and usually having greater resistance to erosion (Table 3).

Table 3

The property and behavior of soils based on textural class.

Property/Behavior	Sand	Silt	Clay
Surface area to volume ratio	Low	Medium	High
Water-holding capacity	Low	Medium to high	High
Nutrient supplying capacity	Low	Medium to high	High
Aeration	Good	Medium	Poor
Internal drainage	High	Slow to medium	Very slow
Organic matter levels	Low	Medium to high	High to medium
Susceptibility to compaction	Low	Medium	High
Susceptibility to wind erosion	Moderate	High	Low
Susceptibility to water erosion	Low	High	Low if aggregated, high if not

Source: Brady & Weil, 2008.

Recreation and the removal of vegetation can destroy soil structure by exposing the peds to rainfall, which detaches individual particles from the aggregates. These individual particles tend to clog pore space, thereby decreasing the permeability of the soil and increasing surface water runoff and soil erosion (Hammitt & Cole, 1998).

Soil Moisture

Soil moisture tends to decrease as recreational impacts increase due to soil compaction processes reducing soil permeability and the amount of water available to the soil (Figure 6). Soil moisture content can influence the rate of compaction; however, the relationship is complex and also depends upon texture, organic content and forest cover (Hammitt & Cole, 1998).

Organic Matter Content

Organic content in soil samples is of interest due to the fact that susceptibility of a soil to compaction is directly related to the amount of organic matter in a soil, i.e., lower organic matter leads to increased compaction (Greacen, 1980). Organic matter can also improve soil structure by increasing the water-holding capacity. The amount of organic matter in soil is strongly influenced by the biota on the site; however, as discussed above, recreational use leads to compaction, reduction of vegetative cover and organic horizon thickness, and an increase in bulk density (Marion & Merriam, 1985). Reduction or elimination of organic matter on campsites reduces the soils ability to capture and absorb water and to replenish soil microorganisms (Hammitt & Cole, 1998).

Soil pH

Potential hydrogen, or soil pH, is the measure of acidity or alkalinity in a soil. Soil pH is important as it affects the solubility of nutrients, microbial activity, chemical transformations, and the availability of many plant nutrients (NRCS, 1998). Soil pH often varies from extremely acidic (3.5–4.4) to strongly alkaline (8.5–9.0); however, a pH range of 6 to 7 is most favorable for plant growth due to the availability of nutrients in this range

(NRCS, 1998). Soils with a pH below 5.5 tend to be deprived of calcium, magnesium, and phosphorus (NRCS, 1998).

In natural systems, soil pH is driven by mineralogy, climate, and weathering (NRCS, 1998). Factors contributing to campsite soil pH may include organic content, current or past campfire ring locations, human and animal waste, soil parent material, underlying geology, and climate (Kuss, 1986; Cole, 1987). Increases in soil acidity have been linked to compaction (Alessa & Earnhart, 2000) and are usually due to an addition of soluble acids at a rate that exceeds how fast they can be naturally removed from the soil (Hausenbuiller, 1985).

Soil Compaction

Soil compaction leads to many related, indirect impacts including reduced water infiltration rates and soil water recharge leading to increased soil erosion, alteration of soil nutrients, and degradation of soil microbial communities (Belnap, 1998; Marion & Cole, 1996). For example, a 2-year study of foot traffic impacts on soil and vegetation at a military base in Colorado indicated that trampling adversely affected bulk density, water infiltration, vegetative cover, litter, and erosion (Whitecotton et al. 2000).

Manning (1979) explains that soil compaction and the resulting indirect effects can be explained using a seven-step cycle (Figure 3). The first step in the cycle following initial trampling is the reduction or removal of leaf litter and humus. Trampling reduces their particle size, making this light-weight organic material susceptible to erosion through surface water runoff. In some places, surface litter is also raked away for fire safety reasons (Hammitt

& Cole, 1998). The second step, loss of organic material necessary, may or may not occur, depending on the environment, topography, and extent of vegetative cover (Monti & Mackintosh, 1979). While the second step may or may not occur, the third step, reduction in soil macroporosity or compaction, always occurs. Compaction (Hammitt & Cole, 1998) eliminates pore space necessary for providing oxygen and water to the soil microbial community and vegetative roots (Gershuny, 1993). Reduction of the soil macroporosity triggers conditions that affect steps four, five, and six. Because macroporosity availability is the primary method for moving air and water throughout the soil, compaction seriously reduced the soil’s ability to allow air and water to

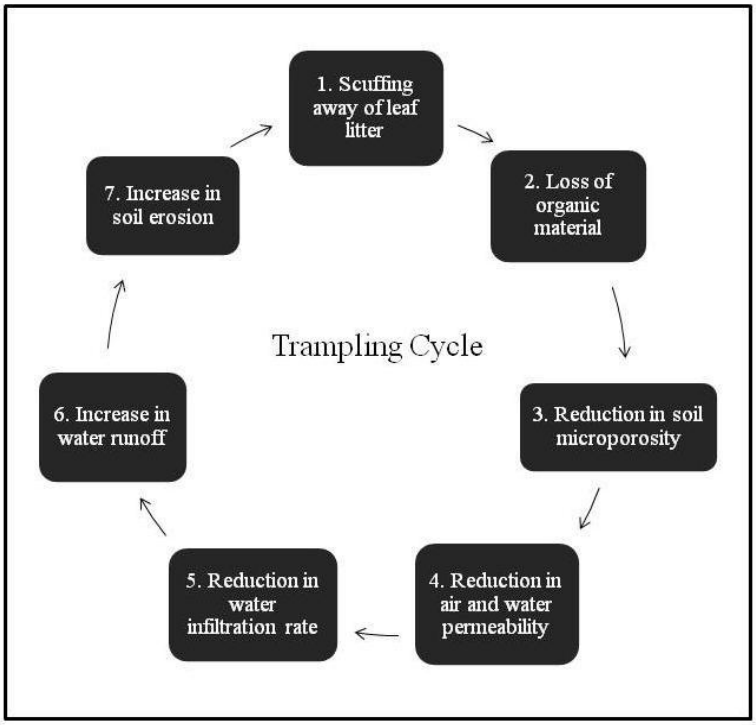

Figure 3. Soil impact cycle resulting from trampling (adapted from Manning, 1979).

permeate, thus reducing infiltration rates and increasing water runoff. These processes lead to step seven, an increase in the potential for soil erosion, particularly when the topography includes steep slopes and easily eroded sandy soils, and soils with highly mobile organic content (Hammitt & Cole, 1998). Once this process has occurred, soil and vegetation recovery can take decades or centuries depending on the intervention method implemented.

Subsurface Ecosystem

While physical impacts of recreational disturbance have been documented, the effects of these impacts on the subsurface ecosystem function and nutrient cycling have received relatively little attention and remain poorly understood, despite their obvious ecological significance (Zabinski & Gannon, 1997). The same disturbances that impact soil physical properties can affect soil biota structure and community composition, resulting in changes in soil nutrient cycles and thereby affecting plant establishment and growth (Setälä et al., 2000). One study conducted by Zabinski and Cole (2000) confirmed these claims, finding that soil conditions, including microbial community structure, nutrient availability, and the density of viable seed, were significantly affected by recreational use. Functional diversity of the microbial community on campsite soils was decreased by 44% relative to soils from undisturbed sites (Zabinski & Cole, 2000).

Soil microorganisms play a key role in determining the structure and function of plant communities. Soil macro and microorganisms are the link between mineral reserves and plant growth (Zabinski & Gannon, 1997). The cycle that allows nutrients to flow from soil to plant is only possible with the help of the soil microbial community (Gershuny, 1993). Soil surface disturbance and altered vegetation can influence the structure and composition of soil microbial communities, inducing changes in soil nutrient dynamics and functional diversity (Setälä et al., 2000).

Intensity of Impact

One of the primary reasons wilderness areas are protected is to provide opportunities for recreation. Negative impacts on wilderness are an inevitable consequence of recreation, leaving land managers to decide the level at which impact becomes unacceptable based on the wilderness management plan. Research shows the heaviest impact occurs at the center or "core" area where camping activities are concentrated and the degree of impact decreased out through the "intermediate" and "periphery" zones (see Figure 4; Cole & Monz, 2004). This research is significant as it suggests that due to the short amount of time needed to cause significant new impacts, increased use and overcrowding can quickly lead to the establishment and proliferation of new campsites.

Packstock Impacts

As demonstrated above, significant research has been devoted to the recreational impacts of hiking and backpacking in wilderness; however, relatively little attention has been paid to packstock impacts. One of the major reasons for this disparity is that biophysical effect of packstock use is so pervasive that it is difficult to differentiate

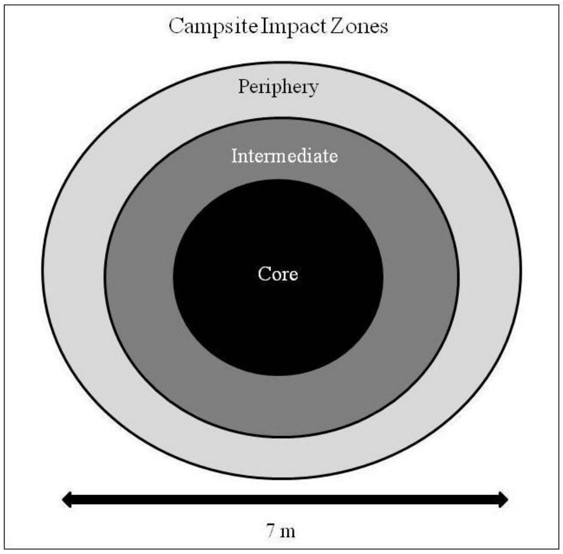

Figure 4. Core, intermediate and periphery zones of campsite impact (Cole & Monz, 2004).

between packstock and non-packstock impacts from one campsite to another with reasonable certainty (H. Castren, personal communication, February 11, 2009).

While it may be difficult to pin the blame of impact on a specific user group on a case by case basis, the few studies that do exist suggest packstock causes significant campsite degradation compared to those of hikers (Weaver & Dale 1978; Cole 1983). Research shows that backpacker and packstock use directly impact wilderness vegetation (Olsen-Rutz et al., 1996; Leung & Marion, 2000), soils, water, wildlife and aesthetics by damaging plants, denuding and compacting soils, leaving behind wastes, and coming in contact with other wilderness visitors and wildlife (McClaran & Cole, 1993). However, the potential for packstock to cause impact is more pronounced because their weight is concentrated onto a relatively small surface as a result of the size of their hooves (Hammitt & Cole, 1998).

Campsite Condition Monitoring Methods

The overall goal of campsite impact measurements is to devise a system that allows for a large amount of information gathered as efficiently as possible.

Recreation Opportunity Spectrum Evaluation System

Originally formulated in the late 1970s for use on public lands in the Western United States, the Wilderness Recreation Opportunity Spectrum (WROS) is a planning framework that was quickly adopted by federal land-management agencies as a way to provide a uniform, objective method of evaluating user impacts on wilderness sites (Clark & Stankey, 1979). The ROS utilizes a zoning framework designed to give managers guidelines on how to plan for diverse recreation opportunities within six “opportunity classes” ranging from urban to primitive (Clark and Stankey, 1979; Hammitt & Cole, 1998).

For primitive or wilderness applications, the ROS system includes a rating worksheet which documents special comparisons to other sites, such as distance to water, constructed trail, and closest campsite adjacent to the site being assessed. Similar to other techniques, the data sheet includes an impact rating of 1-3 for site characteristics such as vegetation cover, mineral soil cover, vegetation loss, mineral soil increase, tree damage, root exposure, development, cleanliness (including number of fire scars), total campsite area, barren core camp area, social trails, and occupied campsites within sight and sound.

Condition Class Estimates

An example of a classic monitoring system that includes many variations is called Condition Class Estimates (CCE). CCE is a system where the user quickly assigns a class rating, usually 1 through 5, to provide a relative overall estimate of the impact level on each site monitored. The basis for this system was originally created in 1978 by Sidney Frissell in Minnesota’s Boundary Waters Canoe Area Wilderness, and later modified by David Cole while conducting research in the Bob Marshall Wilderness Area (Frissell, 1978; Cole, 1989). The updated Bob Marshall Rapid Estimation Procedure (BMREP) was modified from earlier versions of condition class estimates to allow for each parameter to be field-recorded separately (Cole, 1983). Previous versions combined tree trunk damage and exposed roots into one question; however, the revised system assigns each aspect a unique category. Similar improvements were made to differentiate between campsite development and cleanliness parameters. Additional improvements included precisely defined measurement techniques and removing the vegetation composition parameter. These changes add a few minutes to the method, but still allow it to be one of the fastest methods available (i.e., an average of 15 minutes per site), making it a reasonable option for wilderness areas experiencing budget cuts and relying on seasonal employees to monitor site conditions (see Appendix A). The BMREP was the CCE method selected for 2008 campsite impact monitoring at Waptus Lake.

Repeat Photography

Photo points are another tool for documenting change of impact at campsites and are useful when paired with quantitative campsite impact data. Photographs can serve as a useful tool for quickly capturing campsite conditions at a specific time. When photo points are carefully duplicated, the resulting photographs illustrate change over time (Brewer & Berrier, 1984). Repeat photography is limited in its ability to provide quantitative analysis of campsite conditions; however, the method is excellent for reflecting changes in campsite aesthetics that may be missed when using other campsite impact assessment techniques. For this reason, it is a useful addition to existing campsite impact protocols (Brewer & Berrier, 1984).

Campsite Impacts at Waptus Lake

The ROS system was utilized to conduct impact monitoring at Waptus Lake campsites in 1985. Figure 5 displays the results which included 38 active campsites, 26 of which were rated to have “severe” impacts. The information on file at the Cle Elum Ranger District does not include summary ratings for the evaluations or management recommendations based on an analysis of the data.

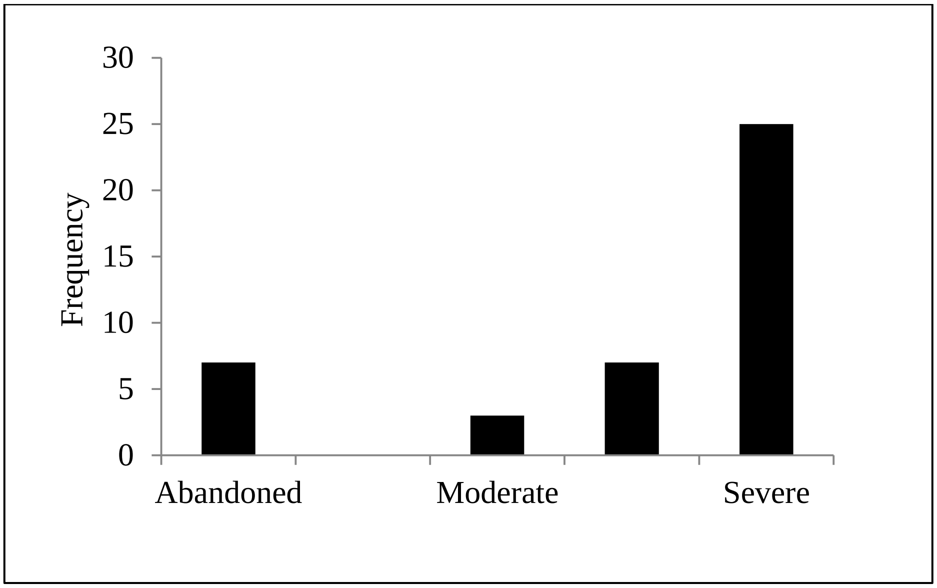

Figure 5. Frequency distribution of 1985 Waptus Lake campsite impact (USFS, 1985).

During July of 1988, ALW Ranger Jon Herman conducted a thorough evaluation of Waptus Lake campsites with the goal of documenting overall numbers of campsites, mapping site distribution, and creating maps of each individual site to illustrate camp features and zones of impact (USFS, 1988). Herman mapped 36 active campsites located on the shore or in close vicinity of Waptus Lake, along with 3 abandoned sites (see Figure 6). Once these sites were located, he created a detailed map of each site including: 1. the core, usually including the fire ring, tent sites, and compacted mineral soil; 2. the intermediate zone, usually surrounding the barren core and includes varying degrees of disturbance, and 3. the "peripheral" natural vegetative zone, which Herman defined as having little visible impact (see Figures 7 & 8). This project also involved the use of repeat photography to help document campsite conditions. Photographs from various vantage points were taken to display the current condition of each campsite. The location of each photo point was indicated on his map with the symbol of a camera. Results of Herman's Waptus Lake Wilderness Report (USFS, 1988) found campsites to be heavily impacted from both packstock and hikers. Impacts were listed as "severe" at most the lakeshore sites at and a few of the campsites located away from the lake due to frequent stock use. The report noted that use patterns seemed the busiest during the middle of the week, and it was during these mid-week times that user violations were occurring. Several strategies for addressing the Waptus Lake impacts were recommended, including: prohibiting packstock grazing and tethering within 200 ft of the lake; designating a packstock "storage area" away from the lake; designating the largest site adjacent to the lake as day use only, and consideration of a permit system (USFS, 1988).

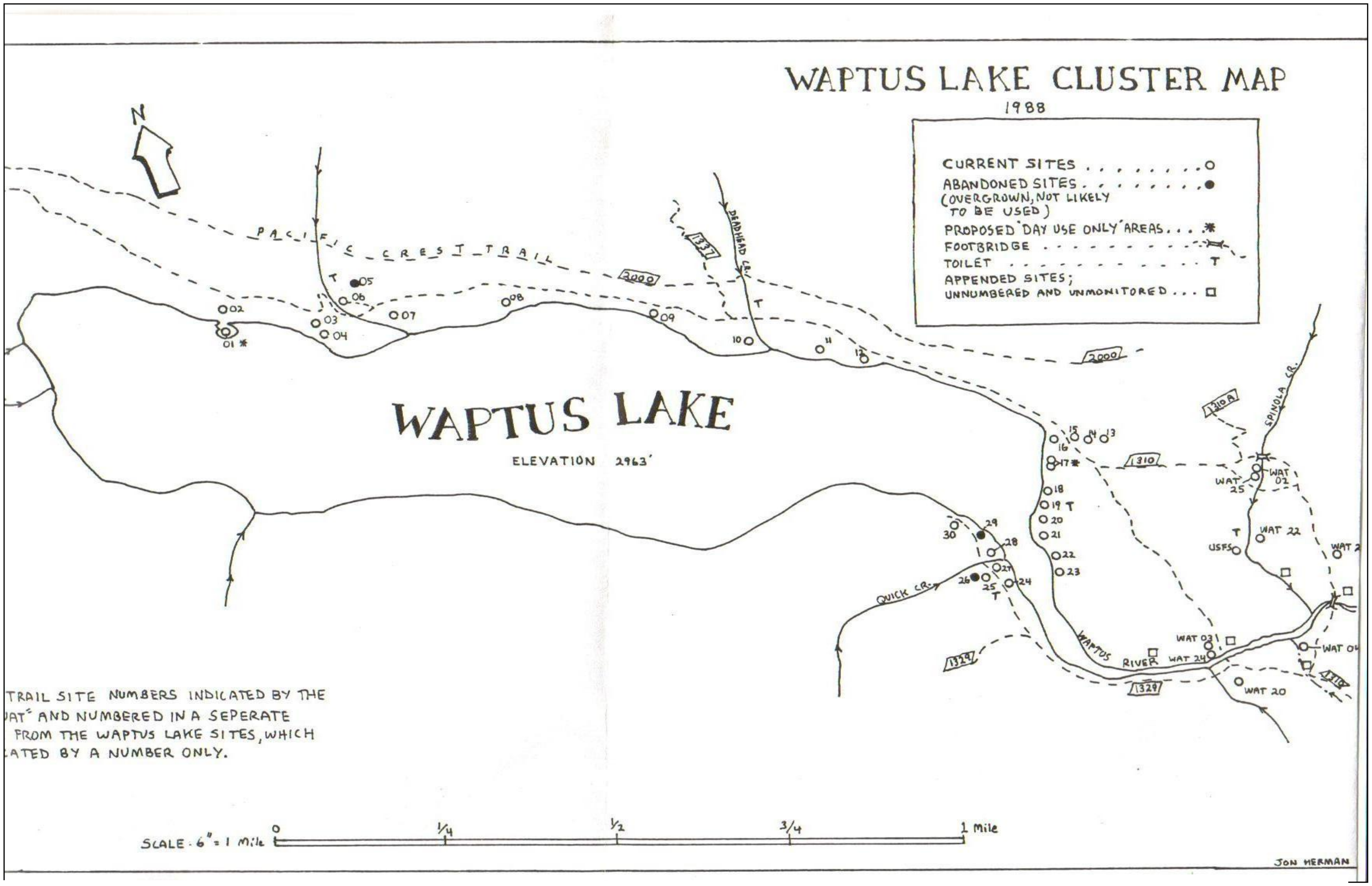

Figure 6. Map illustrating 1988 campsite locations around Waptus Lake (Herman, 1988).

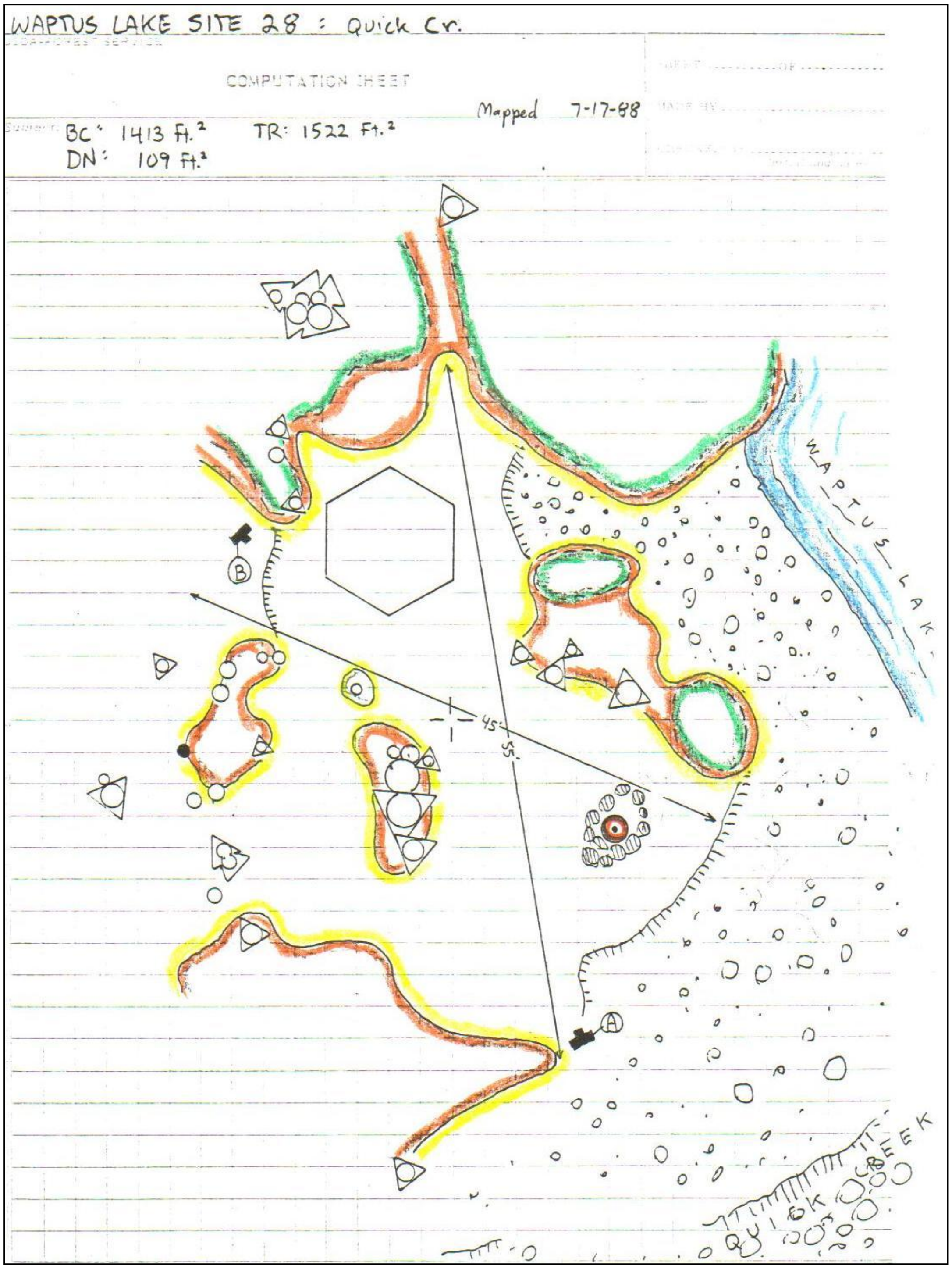

Figure 7. Example of J. Herman’s 1988 individual Waptus Lake campsite inventory drawings.

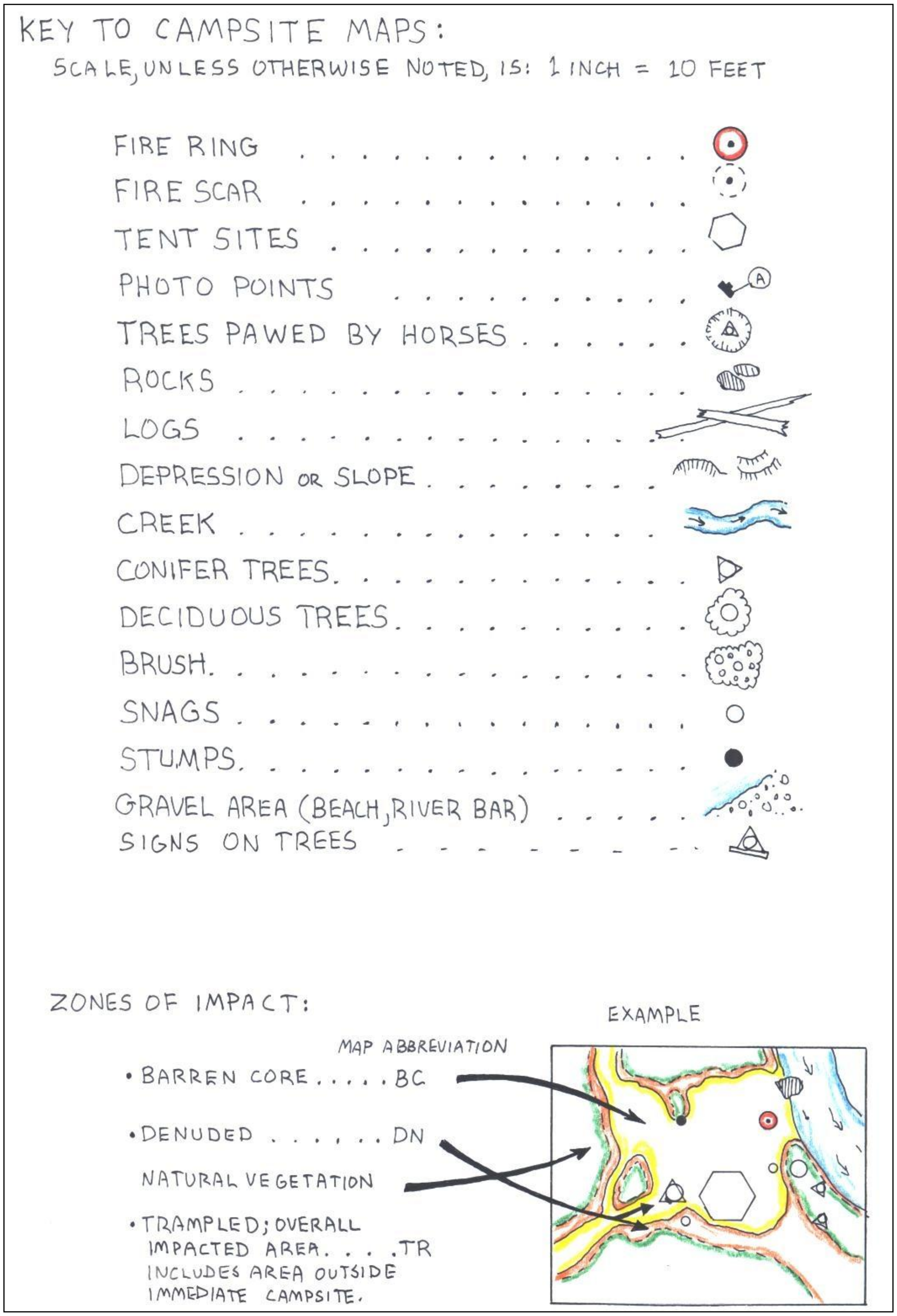

Figure 8. Key to J. Herman’s 1988 Waptus Lake campsite maps.

Wilderness Use Trends

Baseline Data

Baseline data allows land managers to develop a profile of wilderness conditions at time periods in order to assess how resource conditions are changing over time. The Wilderness Act stipulates that managers will document use in order to: 1. improve wilderness management; 2. improve acquisition and use of knowledge from wilderness; and 3. improve assessment status and trends. Systematically documenting use serves at least three important purposes. First, it is a means of measuring how human use and resource conditions change over time (Watson, Cole, Turner & Reynolds, 2000). Second, it provides managers with baseline information on which to base management decisions. Third, they aid managers in evaluating the effectiveness of restoration efforts or other management intervention strategies.

Barely one-half of the wilderness areas in the National Wilderness Preservation System (NWPS) have baseline data. This data gap may be caused by multiple factors, including improper wilderness budget allocations (Cole, 2004) and a lack of personnel trained in wilderness campsite condition evaluation and assessment (Colistra & Flood, 2005). The data that do exist are at risk as most are recorded on paper and filed manually. These paper files are in jeopardy of being lost or forgotten (Cole, 2007).

Monitoring Wilderness Use

Nationally, the use of wilderness areas has steadily increased since the passage of the Wilderness Act in 1964 (Cole, 1996). Use of the NWPS increased 6.3% between 1965 and 1994, with most protected area visits occurring in 1987 when 287 million visits were documented (Cole, 1996; Cordell, Betz & Green, 2008). Use trends dropped slightly during the years following the 1987 visitation record, and then returned to the record levels in 1998 and 1999 (Cordell et al., 2008). National use trends dropped slightly in the early 2000s, but rebounded to high levels again in 2006 and 2007 (Cordell et al., 2008). This information is contrary to reports published in the late 1980s claiming that wilderness use was stable or declining (Lucas, 1989; Lucas & McCool, 1988), at least one-half of all wilderness areas experienced their highest use during the 1990s, while 42% had peak use in the 1980s. The flaw in the declining use claim was a result of mathematical error (Cole, 1996). Hypotheses about visitor use levels were made based on inaccurate assumptions that declining growth implies declining use. In order to demonstrate declining use, the data would need to show a negative growth rate (Cole, 1996).

Additional claims of declining wilderness use were based on use per acre of all United States wilderness areas combined. When the Wilderness Act was passed in 1964, 9 million acres were included in the system. Additional lands have been added slowly with the exception of a major addition of 56 million acres of Alaska wilderness in 1980. Since the Alaskan wilderness area experiences only minimal use, it doubled the size of the NWPS overnight, and cut use in half when referring to use per acre. Many recent additions to wilderness areas were added in order to preserve a natural ecosystem and the areas are less desirable for recreation, therefore have minimal use (Cole, 1996). Most of the popular forested wilderness areas are still experiencing increased use and as a result, increased negative ecological impacts. Previous claims that wilderness use is stable or declining can have significant management implications and must be revisited. Reports of declining use may affect policy and budgeting decisions by congressional, legislative and administrative representatives (Cordell et al., 2008).

Demand for wilderness is keeping pace with supply. Statistical analysis shows a significantly positive relationship between additional wilderness acreage and recreational use. Wilderness use in the western U.S. is expected to grow 25-50% over the next 50 years (Loomis, Bonetti & Echohawk, 1999). Research shows that amenity-based development in the western U.S. is at least partially due to the proximity of protected lands and the resources associated with wilderness (Rudzitis & Johnson, 2000). Wilderness designation tends to stimulate economic and population growth in communities adjacent to wilderness areas. In general, wilderness designation blocks access to resource extraction-based industries, but increases economic growth in many other sectors accounting for faster economic growth in counties containing wilderness compared to counties without any federally protected lands (Rudzitis & Johnson, 2000). The dynamic of wilderness designation leading to population and economic growth in areas adjacent to wilderness has potential for increasing the impact on wilderness areas since an increase in visitor numbers leads to the proliferation of many new campsites followed by the environmental degradation associated with an increase in the spatial distribution of campsite impacts.

Unfortunately, managers have not adequately utilized recreation use estimation methods (see Table 4), resulting in poor documentation of visitor use (Watson, Cole, Turner

& Reynolds, 2000). Research conducted in 2000 indicated 63% of wilderness managers in the United States rely on "best guess" methods for basing their management decisions and regulations, only 16 % use methodical systems for tracking recreational use, and 22% cite "frequent field observation" as the basis for their estimates (Watson, Cole, Turner & Reynolds, 2000; McClaran & Cole, 1993).

Table 4

Selected Approaches to Recreation Use Estimation

Technique	Visitor burden	Management cost	Accuracy
External visual observation	None	High	Variable
Stationary internal observation	None	Variable	Variable
Roaming internal observation	None	Low	Low
Mechanical counters	None	High	High
Registration	Low	Moderate	Variable
Permits	Moderate to high	Variable	High
Surveys	Moderate	High	Variable
Indirect estimation	High to low	High to low	Variable
Aerial surveys	High	High	Unknown

Source: Watson, Cole, Turner & Reynolds, 2000.

Effective use estimation is an essential element to understanding area-specific trends and how current trends correspond with the carrying capacity of a given area. Establishment of a carrying capacity is not required by Forest Service management regulations or policy; however, policy does establish that the wilderness resource must be protected from excessive use. Further, this may require limiting visitors through a regulated permit system with the goal of distributing visitor use based on estimates of capacity (Cole & Carlson, 2010). The estimation of use and carrying capacity is an important exercise in establishing management objectives and criteria for the implementation of a regulated permit system. A limited use permit system should only be considered after thorough consideration of the impact problems, as addressing user behaviors can be just as effective at protecting the resource elements (Cole & Carlson, 2010).

In the ALW, users are required to self-issue a free wilderness permit between May 15th and October 15th, by filling out permit forms at designated trailheads. A copy of the permit is carried with the person or group and a perforated portion is deposited in a box at the trailhead. Wilderness permit stubs from 1996 to 2008 have been archived at the Cle Elum Ranger District office. The Forest Service has attempted to estimate use based on these permit stubs. Unfortunately, the data are likely inaccurate due to the “weigh and estimate” method used between 1996 and 2006. The “weigh and estimate” method involves gathering all permit stub from one trailhead for a given year and weighing a sample of ten to determine a sample weight. Once the sample weight is obtained, the ten permits are returned to the population which is then weighed to estimate the number of permits in the population. Once this number has been obtained, it is multiplied by 3.5 (assumed average group size) to estimate overall use. The two major problems with this method are that the weight of the permit paper-stock varies from very thin paper to thick cardstock and the assumed average group size has not been confirmed through sample estimates (J. Morrow, personal communication, January 23, 2009). Due to these reasons, this method is no longer being used in the Cle Elum Ranger

District.

The ALALMP estimated that wilderness use would increase at a rate of 7% a year between 1981 and 2000 (USFS, 1981); however, limited data and lack of analysis present a challenge in determining if this prediction was accurate. While data are limited, trends for the Mt. Baker-Snoqualmie and adjacent Okanogan National Forest have been estimated through the National Survey on Recreation and the Environment (USDA Forest Service, 2004; see Table 5). Between 2000 and 2004, there were over 2.7 million wilderness visits in the Mount Baker-Snoqualmie and Okanogan National Forests.

Table 5

Percentage and number of people age 16 and older participating in outdoor recreation by age group between 2000 and 2004 on the Mount Baker-Snoqualmie and Okanogan National Forests.

Mount Baker-Snoqualmie National Forest	Age (%)				(n)
Activity	16-34	35-54	Over 55	All Ages	All Ages (n)
Day hiking	60.4	58.5	38.4	53.7	2,588,131
Visit a wilderness or primitive area	60.2	53.0	38.6	51.5	2,484,883
Developed camping	49.8	46.2	26.4	42.1	2,028,249
Primitive camping	38.9	32.5	16.5	30.3	1,461,192
Backpacking	31.3	25.5	9.2	23.0	1,111,160
Horseback riding on trails	8.7	10.0	4.0	7.9	382,224
Okanogan National Forest					
Activity	16-34	35-54	Over 55	All Ages	All Ages (n)
Day hiking	60.3	59.7	40.0	54.0	223,079
Visit a wilderness or primitive area	61.2	55.1	40.2	52.8	217,831
Developed camping	49.1	45.9	28.5	41.8	172,641
Primitive camping	40.1	33.4	18.8	31.4	129,482
Backpacking	31.7	27.0	10.7	23.8	98,200
Horseback riding on trails	9.0	10.8	4.9	8.4	34,674

Source: Adapted from USDA Forest Service (2004). *Note*. Recreational activities that were not directly related to this thesis were deleted from the table.

Wilderness Management

The overall goal of wilderness management as dictated in the Wilderness Act is to maximize recreational opportunities for the public, while ensuring that levels of impact associated with visitor use do not exceed acceptable levels specified in corresponding land management plans. Due to constrained budgets, it is uncommon for USFS administration and the public to hold recreation managers accountable for management plan compliance issues, inadequate objectives, data, or inability to justify the actions taken (Cole, 2006). Rather than basing action plans on recent science, management decisions based on common sense and personal experience has been common.

The Forest Service bases much of their management strategy on the Wilderness Management Model (see Figure 9), which directs the agency to "protect and perpetuate wilderness character" and to evaluate whether wilderness character is degrading, stable, or improving over time (USFS, 2007). The vertical axis represents wilderness character, improving upwards. The horizontal axis represents the amount of modern human influence on wilderness character, with increasing influence to the right. The diagonal line shows the relationship of increasing human influence causing a decline in wilderness condition. A goal of wilderness management (A) is to narrow the gap between Conditions in Wilderness "X" and the legal, and ultimately, absolute wilderness conditions (USFS, 2007). The important point illustrated by figure 8 is that many wilderness areas are still recovering from impacts prior to wilderness designation. After wilderness designation, the initial goal is to stabilize, then improve the diagonal trajectory (L. Therrell, personal communication, May 9, 2011).

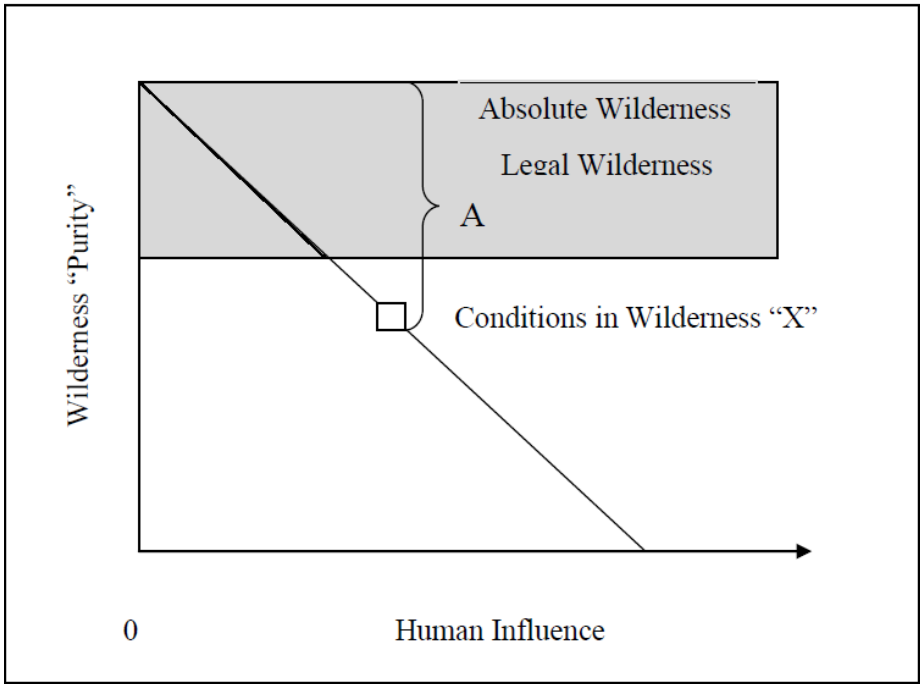

Figure 9. The Wilderness Management Model. Adapted from USFS Forest Service Manual, FSM 2320 – Recreation, Wilderness, and Related Resource Management (2007).

Many wilderness areas are working to revise land management plans in areas where the majority of campsites are out of compliance due to size, level of impact to vegetation and soils, and proximity to water. These processes present an opportunity to narrow the gap between science and current management practices. Integrating current scientific knowledge into management plans adds credibility and provides an opportunity for managers to apply conceptual approaches to complicated problems (Cole & Wright, 2004).

Land managers are continuously struggling to satisfy two primary components of the Wilderness Act: recreation opportunities and resource protection (Leung & Marion, 2000). The language of the Act requires managers to find a compromise between unrestrained (free and natural conditions) and intentional human manipulation as a response to recreation impacts. Intentional manipulation may be in conflict with the Act; however, failure to respond to recreational impacts diminishes the overall character of wilderness and condones mediocrity in these protected landscapes (Cole, 2007).

Federal agencies have worked together to develop tools for helping land managers complete a thorough analysis process to assist in making decisions regarding intentional manipulation to protect wilderness conditions (Cole, 2007). One such tool, the Minimum Requirements Decision Guide (MRDG) leads managers through steps that help them determine if administrative action is warranted, and if so, the selection of the minimum method or tool that is within the constraints of law and agency policy. This tool helps to balance and justify the compromise between intentional manipulation and prohibited uses outlined in the Wilderness Act by providing exceptions to the prohibited uses listed in Section 4(c), only after a thorough analysis of the need for action and alternatives has been considered (Arthur Carhart National Wilderness Training Center, 2010).

Another promising management tool is the analysis of area-specific carrying capacities, which defines the maximum amount and type of use that can be sustained without causing unacceptable impact to the wilderness resource elements (Cole & Carlson, 2010) or particular wilderness zone. For example, a transition zone near a trailhead may be able to sustain more use than a comparatively fragile sub-alpine zone located many miles inside a wilderness in a pristine area. Carrying capacity analysis based on thoughtful management objectives can help inform decisions about other actions such as use limits (Cole & Carlson, 2010).

In order for land managers to respond to growing impacts, they need to be updated with the most recent wilderness research findings that are influencing on-the-ground restoration strategies in wilderness areas and engaging these strategies and other management options across the wilderness landscape. Protected area research has historically made significant contributions to the education and consequent actions of land managers, and has influenced other major educational programs, like Leave No Trace (Christensen & Cole, 2000; Cole, 2002). A variety of management approaches are available to address problems associated with overuse and resource degradation in wilderness areas. These range from increasing ranger presence to enforce regulations to limiting visitor use through a permit system or access road closures (see Table 7). A combination of passive, active and educational management approaches may be used alone or in combination for varying degrees of success (Therrell, Cole, Claassen, Ryan & Davies, 2006).

Most management options listed in Table 6 are unambiguous; however, the active restoration option requires additional explanation due to the variety of approaches available and the amount of planning, labor and monitoring needed for success. Common active restoration techniques include: greenhouse propagation of native seed and transport of plants to the restoration site; transplanting established plants from the immediate vicinity of the restoration site into the campsite; and direct seeding of the restoration site with seed collected in the immediate vicinity (Juelson, 2001; Therrell et al., 2006). These techniques applied alone, or in combination with other methods serve three restoration objectives that include: restoring soil stability; maintaining a landscape

Table 6

Selected Approaches to Managing Campsite Impacts

Management approach	Description
No intervention	Allow the wilderness impacts to occur and recover at a "natural" rate.
Regulations and enforcement	Increasing ranger presence in the area to enforce existing regulations that are being violated, or creating new regulations to address campsite impacts and following up with ranger enforcement.
Passive intervention	Closing a social trail, campsite, or larger area by use of rope, stakes, or signs indicating that the area is closed to use for re-vegetation purposes.
Active restoration	Combining passive intervention with selected prescriptions of compost, soil amendment, plantings, and/or mulch application to aid in increased soil plant recovery.
Educating visitors about low-impact camping techniques	Use of signs and brochures at visitor centers and trailheads aimed at educating users on wilderness ethics and leave no trace principles.
Establishment of a mountain stewards volunteer program	Programs consisting of trainings for volunteers who assist in gathering impact data, monitoring restoration sites, and educate visitors about wilderness ethics and leave no trace principles.
Adaptive Management	Combined with all other management approaches, adaptive management implies careful consideration of field based research and experiments to modify the current management approach for increased effectiveness.
Reducing visitor use	Permit systems regulate the numbers of overnight visitors in wilderness areas. This can also be achieved by closing access roads, effectively adding distance to the access route.

Source: Therrell et al., 2006.

to meet conditions defined by management policy; and improving the aesthetic quality of the environment (Juelson, 2001).

Many wilderness managers are reluctant to implement large-scale restoration projects involving the treatments mentioned above because they do not think the time associated with recovery rates justifies the expense (see Table 7). Results of field-tested methods indicate that greenhouse propagation and transplant yield the fastest results (Table 7); however, the method is expensive and labor intensive (Juelson, 2001). Transferring established plants from the immediate vicinity is effective, but causes additional adverse impacts to adjacent areas (Therrell et al., 2006). Directly sowing native (locally collected) seed has proven to be a cost effective method with positive results (Table 7; Therrell et al., 2006).

Table 7

Estimated Campsite Recovery Time (in years) to 50 Percent Vegetation Cover.

Restoration Method	Years to Recovery
Closure	1000
+ Scarification	200
+ Adding Organics	100
+ Adding Compost	56
+ Direct Seeding	31
+ Transplanting Seedlings	19
Transplanting, but not seeding on plots with organics and compost amendments	36

Source: Cole & Spildie, 2007.

Additional challenges are associated with the management directive recommending setbacks from trails and water bodies. Enforcement of this management directive would requires decommissioning of existing sites within the setback area, potentially establishing new sites to accommodate users, and continued monitoring for enforcement of the new regulation. However, this dilemma creates an opportunity for further examination of campsite monitoring methods seeking out the most effective, user-friendly techniques for wilderness managers and employees to document campsite impact data.

Many nationally protected wilderness areas have region-specific management guidelines. For example, Yosemite National Park has established guidelines for the number and location of wilderness campsites, along with implementing a permit system that limits use to a maximum number of visitors per day (Lawson & Newman, 2001). In order to protect wilderness ecology and the wilderness experience, Yosemite developed a policy that requires wilderness campsites to be located at least 30 m from the nearest body of water or designated trail. Once this policy was in place, Yosemite determined their current compliance rates by conducting a spatial analysis of existing campsites. The analysis identified thirty campsites within 30 m of water or trail, resulting in the decommissioning of thirty campsites in the Lyell Canyon region of the park (Lawson & Newman, 2001).

As campsite impact monitoring protocols improve, they will help to provide better documentation of campsite impact boundaries and the expansion of heavily impacted zones, giving wilderness managers better data about changing conditions. Improved data collection can identify significant changes in impact, which will help land managers take action to curb impact before it reaches the level of disturbance that may take years, even centuries to recover (Douglas & Bliss, 1977; Cole, 2007). In general, wilderness managers should develop an impact management plan that utilizes multiple approaches to strategically address impacts in order of priority, rather than relying on just one method for all situations (L. Therrell, personal communication, April 19, 2010).

Management decisions for the Mount Baker-Snoqualmie and Okanogan-Wenatchee National Forests are guided by the Land and Resource Management Plan (LMP), which categorizes each wilderness area using the WROS system. The WROS categories include pristine, primitive, semi-primitive, and transition (USFS, 1990). These categories represent the range of experiences from maximum solitude found in pristine areas to the more congested transition areas, typically found near wilderness boundaries and trailheads. Each LMP wilderness area classification implies specific biophysical, social and managerial standards that dictate acceptable conditions and management directives (see Table 8). Even though Waptus Lake is located 14.5 km within the wilderness, it is categorized as a transition area due to the popularity of Waptus Lake, the number of trails that converge at the lake, and the proximity to the Pacific Crest National Scenic Trail (PCNST) (J. Morrow, personal communication, April 23, 2010).

Management of the ALW and Waptus Lake are not guided by the LMP because a separate management plan was created for the ALW and area specific plans take precedence over forest-wide management plans (D. Davis, personal communication, April 22, 2010). The Alpine Lakes Area Land Management Plan (ALALMP) sets wilderness management

Table 8

USFS Land and Resource Management Plan Wilderness WROS Category Standards Compared with the Alpine Lake Wilderness Area Land Management Plan Standards

Indicators	Pristine	Primitive	Semi-Primitive	Transition	ALALMP Transition
Bare and compacted mineral soil in campsites (m^2)	20.9	37.2	58.1	92.9	37.2
Number of trees with root exposure	0	4	6	10	No directive
Maximum number of social encounters while traveling	1	7	10	10-20	7
Maximum party size (people and packstock)	12	12	12	12	12
Number of other campsites visible when occupied	0	1	2	3	2
Setbacks from other camps, trails, meadows, lakes and streams (m)	No directive	No directive	No directive	No directive	61
Packstock setbacks with the exception of crossings and watering (m)	61	61	61	61	61

Source: USFS, 1981 & 1990.
Note. ALALMP describes packstock setbacks to be located “outside the foreground”; however, packstock policy changed to 61 m setbacks in 1988.

standards that are considerably more restrictive in the transition category compared to the LMP standards (Table 9). According to the ALALMP regulations, campsite core areas with bare and compacted soil shall not exceed 37.2 m^2 and recommended campsites setbacks are

61 m from other camps, trails, meadows, lakes and streams (USFS, 1981). Maximum social encounters are reduced from the 10-20 allowed under the LMP to 7 allowed under the ALALMP, and the number of other campsites visible when occupied is reduced from 3 in the WROS Transition classification to 2 campsites allowed for under the ALALMP.

The ALALMP directives are restrictive, presumably to add greater protection for resource elements; however, data collected in 1985 clearly indicates that nearly 100% of the campsites were out of compliance with the standards. Since the plan was published in 1981, it is reasonable to assume the campsite conditions were out of compliance when the plan was written. This assumption is also substantiated by anecdotal observations of agency personnel and the public (L. Therrell, personnel communication, May 9, 2011).

CHAPTER III

STUDY AREA

Location

The ALW is the most visited and second largest wilderness area in Washington State (Cole, Watson, Hall, & Spildie, 1997). The area encompasses approximately 1,590 km^2 (Cole et al., 1997) which are accessed by 47 trailheads and 990 km of trail spanning the Central Cascade Range of Washington State (Figure 1; USFS, 2010; University of Washington, 1972). The approximate boundaries include Snoqualmie Pass and Interstate 90 to the south, Stevens Pass and U.S. Route 2 to the north, Blewett Pass and U.S. 97 to the east, and an irregular boarder following watershed boundaries, excluding roadbed areas, west of the Cascade Crest. The elevation ranges from less than 305 m in the lowest valley to 2,870 m at the peak of Mount Stuart on the east. The highest areas feature bare rock, meadows, glaciers, and snowfields, which melt and drain to feed the region's many streams and rivers that descend to the lower valleys and lakes. The ALW spans parts of four counties including King, Kittitas, Chelan, and Snohomish. The land is jointly managed by the Mt. Baker-Snoqualmie and Okanogan-Wenatchee National Forest, and divided into four separate ranger districts (USFS, 2010).

This wilderness area was named "Alpine Lakes" to reflect the presence of the 727 mountain lakes scattered throughout the valleys and high ridges (Mt. Baker-Snoqualmie National Forest, 2007)**.** This network of lakes helps to sustain the rich biodiversity of the region, and is also one of the features that attract 150,000 annual visitors.

Waptus Lake is located in the western section of the Okanogan-Wenatchee National Forest, within the Cle Elum Ranger District in a northwest-trending valley, about 37 km northwest of Cle Elum and 11.3 km northwest of Salmon La Sac (Wolcott, 1973). It sits at an elevation of approximately 914 m in the upper Waptus River Valley, and includes parts of sections 1, 2, 3, 10, 11, and 12 in Township 23 north and Range 13 east of the Willamette Meridian. Waptus Lake is the second largest lake in the ALW, measuring 2.4 km long and 0.4 km across at its widest point (USFS, 1988; Beckey, 2000), and totaling 5526.6 m^2 (Wolcott, 1973).

The primary access route to Waptus Lake is from the Salmon La Sac trailhead, following the Waptus River Trail (1310). Additional routes providing access to Waptus Lake include the Waptus Pass and Quick Creek Trail (1329) via Polallie Ridge Trail (1309) to the south. The Pete Lake Trail (1323) also provides access over Waptus Pass via the Tired Creek Trail (1322). Other access routes from the northeast include Trail Creek Trail (1322) via the Cathedral Rock Trail (1345). The Pacific Crest National Scenic Trail (PCNST; 2000) runs adjacent to the north shore of Waptus Lake and provides access from both the south and the north (see Figure 10).

Geology and Geomorphology

The Cascade Range is a western rampart of the vast North American Corillera, featuring accreted terranes and a cover of sedimentary and volcanic rocks (Tabor, Frizzell, Booth, & Waitt, 2000). The bedrock of Waptus Lake and surrounding area consists of the Swauk Formation, sandstone of alluvial origin composed of layers of

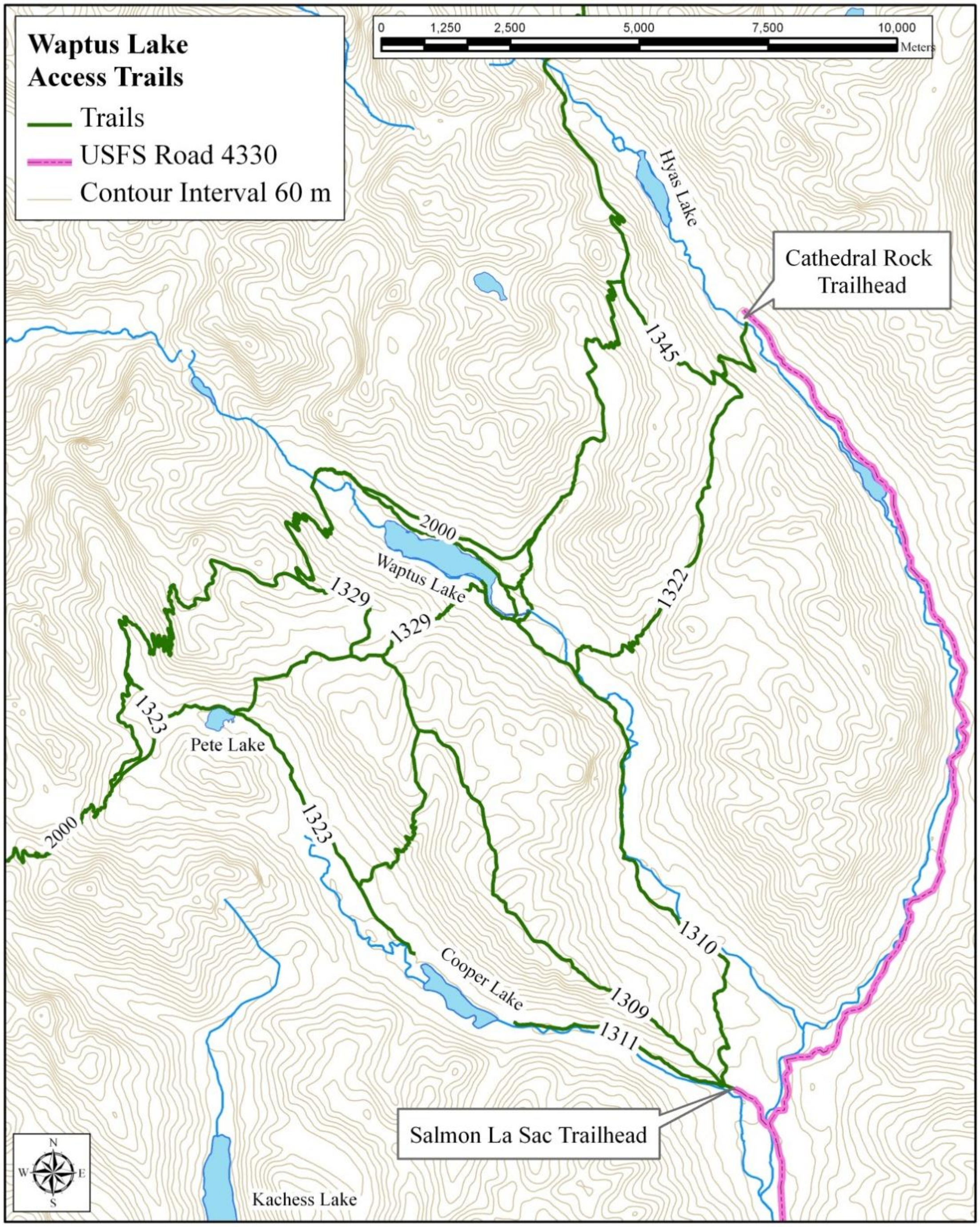

Figure 10. Access trails connecting to Waptus Lake.

siltstone, argillite, and conglomerate (Tabor et al., 1993). The 8,000 m thick Swauk Formation was deposited during the Eocene period after the Oligocene and Miocene uplift of the Stuart Range batholith. The Swauk Formation overlies serpentine of the Ingalls Tectonic Complex. The eruption of the volcanic rocks that formed the Teanaway Basalt followed and overlies the Swauk Formation deposits (Tabor et al., 2000).

The Cascade Range is comprised of accreted terranes with a cover of sedimentary and volcanic rock. The Range is thought to have risen during the late Miocene and Pliocene time (Tabor et al., 1993), forming high topographic relief that creates a barrier effect to Pacific winds and moisture (Lasmanis, 1991). The Waptus Lake region has been deformed by folding and faulting caused by a branch of the adjacent Straight Creek Fault, the main north-south strike-slip fault in the state of Washington, which follows the Cascade Range from central Washington into Canada, and possibly Alaska (Tabor et al., 1993).

The steep and jagged topography that encompasses the ALW lies within the North Cascades physiographic province. Most valleys in this province were shaped by small glaciers, leaving behind late Pleistocene alpine glacial drift deposits (Tabor et al., 1993).Waptus Lake occupies a classic glacial trough (see Figure 11) and is surrounded by horns and arêtes (USFS, 1981).

The southeast shore of Waptus Lake, which hosts the majority of campsites, is comprised of side stream alluvial deposits which impounded the lake in the glacially eroded valley (Tabor et al., 2000; Wolcott, 1973). The relatively steep northern shore

Figure 11. Waptus Lake from the Southeast shore. Note the glacial trough which Waptus Lake occupies and the horn of Bear's Breast Mountain. Photo: D. Batura.

hosts numerous campsites on alluvial fans. The relatively isolated northwestern and southern shores exhibit several Pleistocene and Holocene alluvial fans.

Over time, the glacial activity created a stunning landscape that attracts people seeking solitude, beauty and the physical challenge of wilderness travel. The visual landscapes are important to this context, since the dramatic beauty of the ALW region has played a large role in setting the land apart from others in the state, and ultimately declaring it a designated wilderness area.

Climate

The three climatic controls of the Pacific Ocean, semi-permanent high and low pressure systems, and the orientation of the Cascade Mountain Range combine to regulate the area’s climate (Kruckeberg, 1991). The east slopes of the central Cascades feature dynamic weather patterns that are variable depending on slope and distance from the Cascade Crest. Prevailing west winds lift cool, moist air from the Pacific Ocean towards the Cascade Crest (USFS, 1981). The westerly winds tend to warm and dry as they descend the eastern slopes of the Cascade Range, resulting in warmer and drier summer conditions and colder winter conditions compared to western Washington (WRCC, 2010). This phenomenon is illustrated by examining the difference in climate data between Stampede Pass at the Cascade Crest and at an elevation of 1206 m, and Cle Elum to the east at an elevation of 585 m. Within this 32.2 km range, average annual precipitation decreases from 234 cm to 56 cm (WRCC, 2010).

The proximity of Waptus Lake to the Cascade Crest (9 km to the west) dictates the areas weather patterns, which are similar to those found at Stampede Pass (See Figure 12). The study site features wet and cold winters, contrasted by warm and dry summers. At Stampede Pass, the average January temperature is approximately –3° C and the average July temperature is approximately 16° C (WRCC, 2010; NRCS 2008). Annual precipitation averages range from 127 cm to 210 cm with the majority falling in the winter months as snow. Snowfall usually begins at higher elevations in October and areas remain snow-covered into July (USFS, 1981). Snowfall at Stampede Pass is approximately 10 m a year (WRCC, 2010).

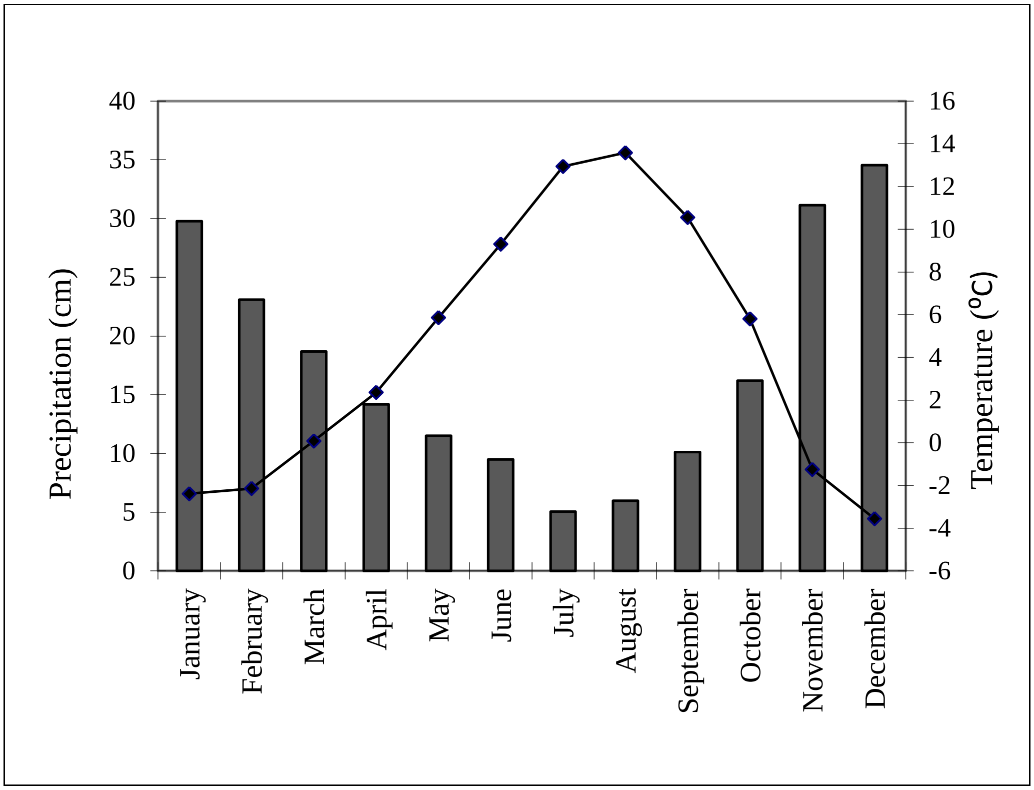

Figure 12. Stampede Pass temperature and precipitation 1971 – 2000 climate normal (WRCC, 2010).

Soils

The soils in the ALW have been formed over centuries through the processes of physical and chemical weathering, vegetation decomposition, humification, and translocation. Over 200 soil types have been mapped and recorded in the Soil Resource Inventories of the Mt. Baker-Snoqualmie and Wenatchee National Forests (USFS, 1981). In general, soils west of the Cascade Crest feature deep, well drained sandy loams in valley bottoms, with gravelly and stony loams on steeper slopes and higher elevations. Soils east of the Cascade Crest have been impacted by glaciation and tend to be shallow and naturally compacted (USFS, 1981). The soils at Waptus Lake are heavily influenced by volcanic ash.

According to the Natural Resources Conservation Service (NRCS) soils data, the predominant soil on the north and south side of Waptus Lake is the Vabus series (see Figure 12; NRCS, 2008). Vabus soils are spodosols, forming in moderately deep to dense glacial till mixed with volcanic ash and found on mountainsides and valleys at elevations of 762 m to 1,463 m (NRCS, 2001). The soil type at the southeast end of Waptus Lake is the Kladnick series (Figure 12), formed in glacial outwash with a mantle of volcanic ash. Kladnick soils are inceptisols, found on young geomorphic surfaces that exhibit minimal horizon development (NRCS, 2008). Unnamed entisols and inceptisols are located at the northwest end of Waptus Lake. These recently-formed entisols and poorly developed inceptisols are fine textures loamy and clayey soils with a cryic soil temperature regime (Buol et al., 2003). The pattern and proportion of the soils are somewhat similar in the area indicated (Figure 13).

Volcanic ash-based soils are especially susceptible to disturbance with erosion and compaction of primary concern. Soil disturbance can happen quickly but the effects may persist for decades (Curran, Green & Maynard, 2007; Page-Dumroese, 1993). For some, soil erodibility is determined largely by soil properties other than texture. This is especially true for volcanic soils, as the physical and chemical properties of these soils make them extremely vulnerable to soil erosion.

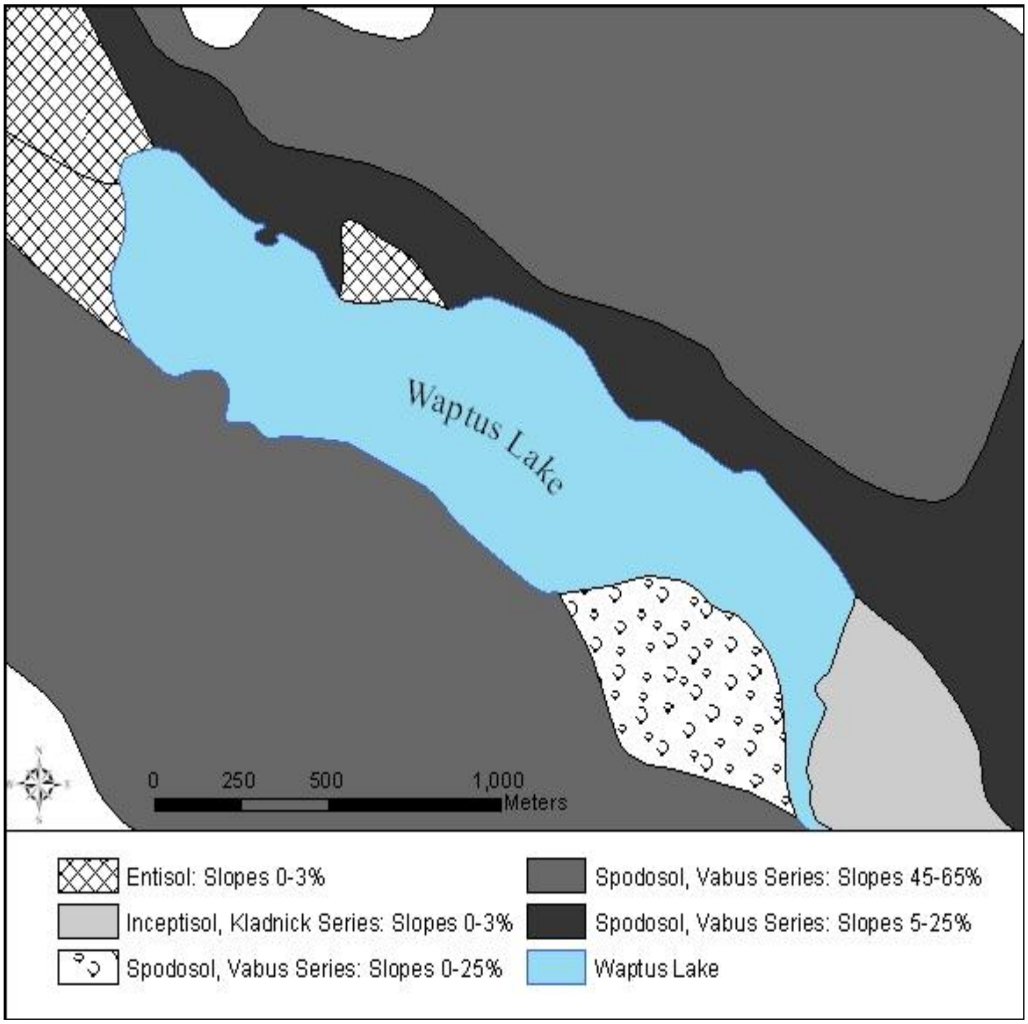

Figure 13. Soils in vicinity of Waptus Lake Soils. Data adapted from NRCS, USDA *Web Soil Survey*. http://websoilsurvey.nrcs.usda.gov/ accessed January 9, 2011.

Biota

Waptus Lake is host to coniferous, mid-elevation forests with a diverse cover of trees, shrubs, and herbaceous perennials (see Figure 14). The landscape is dominated by lodgepole pine (*Pinus contorta*), western red cedar (*Thuja plicata*), and Pacific silver fir *(Abies amabilis)* forests with huckleberry (*Vacinium ssp*) and bunchberry (*Cornus canadensis*) as the most prevalent understory.

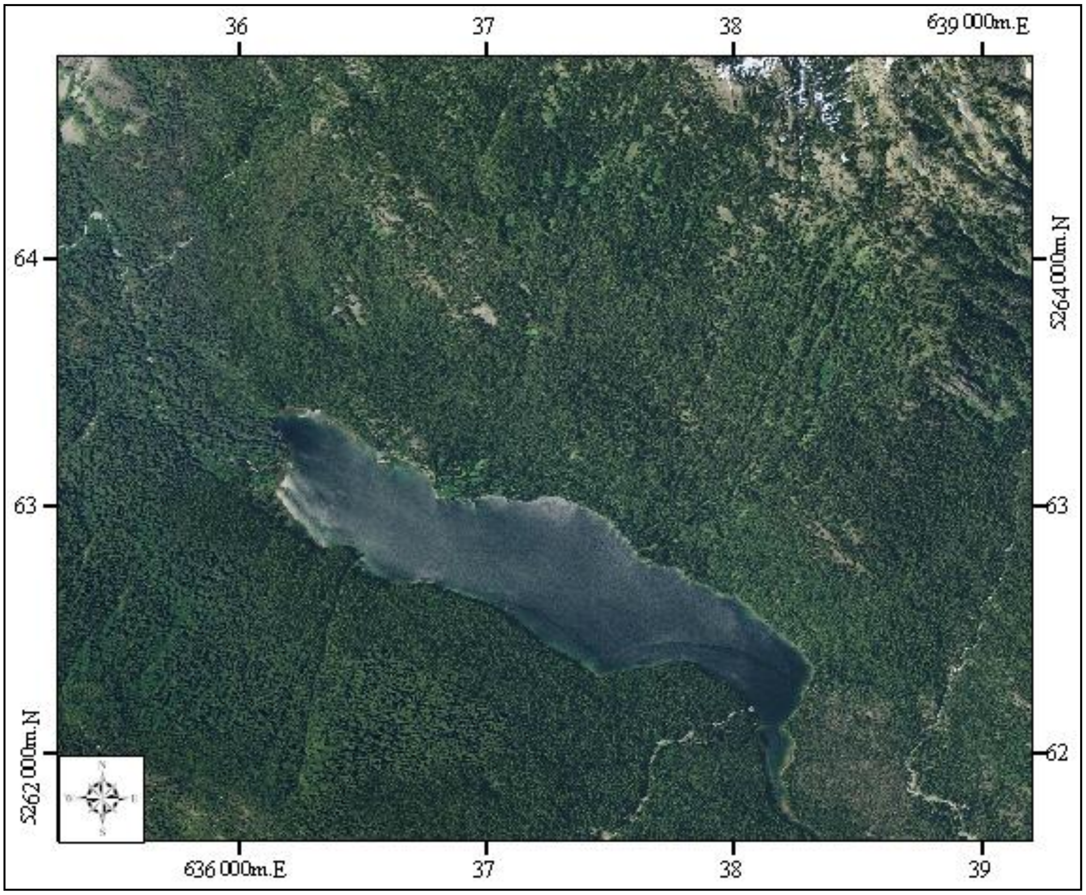

Figure 14. Aerial view of Waptus Lake and surrounding vegetation. Note dominant coniferous forest cover.

Significant lodgepole pine blow down was observed adjacent to the southeast shore of the lake during 2008 field research. Conversations with USFS rangers determined the tree damage to have occurred during the winter of 2006 (J.E. Morrow, personal communication, August 10, 2008). Western white pine (*Pinus monticola*) seedlings are becoming established in the areas dominated by blow down, a phenomenon of note due to the fact that the species only accounted for 2% of the standing volume of conifer species in the Wenatchee National Forest as of 1990 (USFS, 1990).

History and Land Use

The name Waptus was derived from the Sahaptin word “wáptas” meaning “feather” (Bright, 2004). Waptus was likely an important location for native inhabitants, as it was one of the few high lakes that retained native fish populations following the Pleistocene glaciations (Pfeifer, Swayne, & Curtis, 2001).Waptus Lake was frequented by native tribes as a fishing location as evidenced by Splawn (1917):

> Over there is Wap-tus lake. In the long ago it was the home of a huge water serpent which had swallowed so many people who were traveling along the shores of the lake that finally no one dared travel that way anymore. This serpent had been seen many times, raising its head far above the waters and, with a hissing noise, spouting fire from its mouth while its tail lashed the waters into a fury.

The ALW and its surrounding regions have been important to native tribes for centuries. According to the Alpine Lakes Area Land Management Plan (ALALMP), the earliest trails over the Cascade Crest were main routes for tribes located on the east and west (USFS, 1981). Tribes located on the west had trade relationships with other coastal tribes and goods associated with life on the water. The tribes on the east had trade relationships with Plains tribes and their buffalo-derived goods (Knibb, 1982). Hence, these trails over the Cascade Crest served as vital corridors for trading goods, information, and tribal members through intermarriage. While tribes hunted, migrated, and camped within the ALW, the primary settlements were usually along rivers. The ALW serves as the headwaters to four major rivers, however those rivers do not pass through the ALW, so the settlements were mostly on rivers adjacent to the ALW (i.e., Yakima, Wenatchee, Snoqualmie, and Skykomish) with each river bearing the name associated with the predominant tribal inhabitants. Waptus River is a tributary of the Cle Elum River, which feeds into the Yakima River system.

The U.S. Forest Service has played a major role in what is now the ALW since 1905 when the responsibility for national forests was given to the Department of Agriculture. For many years, the U.S. Forest Service managed the land by re-foresting and instituting fire control. Access into the area changed dramatically during the Great Depression when Civilian Conservation Corps (CCC) began to construct trails, fire lookouts, and campgrounds. After trail access was improved, the area became a popular recreation site with many local families setting up permanent camps for a season or longer. Even the Forest Service had a permanent site with a wall tent, corral, and toilet at Waptus Lake (L. Therrell, personal communication, May 9, 2009). During this time, group sizes had not been established and significant recreational impacts occurred as a result.

In the 1960s, environmental organizations increased pressure on Congress to protect this area of natural beauty adjacent to the Puget Sound region. The numerous proposals and subsequent alternatives to those proposals eventually gave way to the ALW designation by President Gerald Ford in 1976. Since then, use has been limited to hiking, hunting, camping, climbing, stock use, outfitter guiding, and a few remaining mining claims.

Waptus Lake is currently accessed by one of the longer lowland river hikes in the ALW. The primary entry point is the Waptus River Trail which begins at the Salmon La

Sac trailhead on the Cle Elum Ranger District. The 14.5 km, undulating Waptus River Trail mostly has a gentile gradient with only 171 m of total elevation gain. Cooper Lake and Cathedral Rock trailheads provide secondary access points and the PCNST runs adjacent to the lake's north shore. Although the Salmon La Sac/Waptus River Trail is long, the route is popular, especially with stock users. Multiple access points make Waptus Lake a central hub for activities such as hunting and fishing. Another reason for this lake's popularity may be the fact that it is located within a one-day hike of approximately 20 other lake destinations (USFS, 1999).

CHAPTER IV

METHODS

Overview

The methods used to assess backcountry campsites at Waptus Lake involved: 1. documenting the spatial patterns of campsites around Waptus Lake; 2. assessing the biophysical condition of each campsite as of 2008 – 2009; 3. comparing 2008 campsite impact ratings with baseline data from 1985 to 1988; 4. analyzing Waptus Lake trailhead data to document backcountry use trends over time; and, 5. providing long-term management and policy recommendations for Waptus Lake in light of the research results. The majority of field research for this study was completed during the summer of 2008 and compaction data was recorded during the summer of 2009.

Spatial and Temporal Patterns of Wilderness Campsites

Spatial Distribution of Campsites

Geographers and landscape ecologists have used various approaches to understand spatial patterns, variations, and relationships through the application of Global Positioning Systems (GPS), geographic information systems (GIS), statistics, and cartography. While this aspect of campsite evaluation has received less attention than biophysical impact assessments, these techniques have been employed in numerous studies including Frissell's (1978) evaluation of campsite impacts of the Boundary Waters Canoe Area Wilderness, and more recently in a ten-year study of the Eagle Cap Wilderness (Cole, 2007). To understand the spatial impacts of recreational use on wilderness resources, focus needs to be upon techniques and methods capable of identifying, quantifying and summarizing the spatial properties of impacts.

Campsite locations within 120 m of Waptus Lake were identified with the aid of Jon Herman's 1988 site map (Figure 3), and recorded using a Garmin etrex GPS. The accuracy of the GPS unit varied from 6-30 m depending upon the density of forest cover at each site. Once collected, these data were put into an ArcGIS database to create a map documenting the overall number and distribution of sites. This information was compared to mapping completed in 1988, noting new sites that have been established since 1988, and those that were abandoned since 1988. Distance from campsites to water, trails, and other campsites were also field verified as part of the BMREP using a 100 m measuring tape. Campsites within 120 m of Waptus Lake are considered Waptus Lake (WAL) sites and campsites greater than 120 m from the lake are considered Waptus Trail (WAT) sites.

Newly established campsites were identified by comparing their location with the 1988 map. Sites present in 2008, but not identified in 1985 or 1988 were considered newly established. These sites were also identified by noting biophysical impacts and anthropogenic modifications, primarily vegetation loss and the presence of features like fire rings, nails in trees, and construction of benches. Abandoned campsites were located with the 1988 site map (Figure 3), 1988 photo points, and by searching for remaining biophysical impacts and anthropogenic features, such as tree damage from packstock, nails, and presence of old fire rings or fire scars. Previously active campsites were considered abandoned when site conditions changed in a manner that suggested it was no longer being used as a campsite. These indicators include substantial vegetation recovery in the campsite core, campsite washout by seasonal streams, natural treefall through the campsite core, or simply that the campsite had recovered to a level that we could not identify its previous location.

Assessing Biophysical Condition of Campsites

Campsites previously evaluated in 1985 using the ROS method and in 1988 by Herman’s hand drawn maps and photo points were revisited in the 2008 campsite census, along with sites that were newly established since the last survey. New impact data were gathered using the BMREP. This method was selected because it is similar to the WROS evaluation system employed at Waptus Lake in 1985, but results in more data, includes additional rating options where appropriate, and provides precisely defined techniques for evaluating conditions. This latter point simplifies the training time and complexity for seasonal employees who may be using the system to assess campsite impacts.

The BMREP collects data covering over 30 aspects of campsite conditions. Data categories include campsite elevation, vegetation type, landform, distance to trails, water, other campsites, firewood, and forage supplies. The BMREP notes the maximum party size accommodated by each campsite, the type of use (foot, stock, river, outfitter), and anthropogenic facilities present (i.e, fire rings, seats, table, meat rack, hitch rail, corral, toilet). Within the campsite perimeter, the BMREP estimates the percentage of vegetation and mineral soil exposure. A visual estimate for percent vegetation was made using the standard AGI Data Sheets-Comparison Chart for Estimating Percentage Composition

(Terry and Chilingar, 1955). Comparisons between the defined campsite area and undisturbed control areas revealed cover class differences in: 1. vegetation loss; 2. mineral soil increase; 3. tree damage; 4. root exposure; 5. campsite development (fire rings, fire scars, hitch rails, toilets, etc.); 6. cleanliness; and 7. social trails. Final measures estimated the camp area by using a 100 m tape, measuring the geometric areas of the barren core and multiplying to determine the total impacted campsite area. Once the data were collected, I assigned the site an impact index number and determined the condition class of each campsite (see Table 9).

Table 9

Bob Marshall Rapid Estimation Procedure Campsite Rating System

Impact Category	Light (1)	Moderate (2)	Heavy (3)	Severe (4)
Numerical Value	20 – 29	30 – 40	41 – 50	51 – 60

Source: Cole, 1989.

I compared Waptus Lake campsite impact index data from 1985 to 2008 in order to determine if campsite conditions had improved, remained the same, or declined. To accomplish this, I assessed the difference between two sets of ordinal scale campsite impact data using the Kolmogorov-Smirnov and Wilcoxon Signed Rank statistical test, because the data set meets the test assumptions and contains greater than 50% of tied ranks (McGrew & Monroe, 2000).

Repeat Photography

Photopoints taken in 1988 were converted from slide film to digital images, then printed to have on hand during field research. While surveying each campsite, photopoints were located by referencing Herman’s detailed site maps (Figure 5), and the printed copies of the 1988 photographs. Once the location was identified, I prepared for the photo by adjusting the lens to duplicate the 1988 photograph as much as possible. Once completed, the photographs were compared and assigned a value based on the rate of change (i.e, 1-5) by visual assessment, relying on changes in near-distance and mid-distance vegetation cover and density to assign a value (see Table 10).

Table 10

Value Based on Rate of Change by Visual Assessment

Value	Rate of Change by Visual Assessment
1	Conditions Significantly Improved
2	Conditions Slightly Improved
3	No Discernable Change
4	Conditions Slightly Worsened
5	Conditions Significantly Worsened

Site Specific, Detailed Measurements

Once all the active campsites were identified, a subset was selected from the total population of campsites evaluated for further analysis. This sub-group of ten campsites was selected from two distinct locations around Waptus Lake including the southeast shore and the northern shore. One control site from the northern shore and another from the southeast shore was also located and measured. Control site transects were 7 m long and selected based on similarities to existing campsites in regard to geographic area, slope, and vegetation cover. The advantage of identifying two distinct geographic sample areas is that it ensures an equal number of sites were chosen from different locations around the lake and the two areas are also comprised of different soil types. A stratified random sampling procedure was used to select five sites from each geographic sample area, ensuring that each site in the population had an equal probability of being selected (Watson, Cole, Turner, & Reynolds, 2000). Once in the field, three sites were replaced due to campsite occupancy. Replacement campsites were determined using a stratified random sampling procedure with the previously selected sites and occupied sites removed from the sample population.

The goal of this in-depth evaluation was to gather additional information on campsite soil properties including: surface mineral horizon texture, soil moisture content, pH, and organic matter content, and soil compaction. Soil surface measures were sampled from four distinct quadrants of each campsite, delineated by northeast, northwest, southeast, and southwest.

Sample Collection for Lab Analysis

Within the ten campsites and two control sites, one soil sample was collected from the northeast, northwest, southeast, and southwest quadrants for a total of 48 samples. Soil samples were surface collected by brushing away any surface debris, then using a plastic trowel to collect the sample from the soil surface to a depth of approximately 15 cm (U.S. EPA, 2000). Each individual sample was sealed in a plastic bag, labeled with the site number and quadrant, and then the four samples from each site were placed in another, larger sealed bag, labeled with the site number and set aside to be carried out of the wilderness with assistance from U.S. Forest Service packstock. Soil samples were collected in August of 2008 during a particularly wet period. According to Stampede Pass climate data, the region received 10.7 cm of precipitation which is nearly twice the average precipitation (5.6 cm) for the month of August (WRCC, 2011).

Coarse Textured Sediment Analysis

Sieve analysis results reveal important information about the properties of a soil. Coarse textured soils typically have low water holding capacity, organic matter content, and low susceptibility to compaction and erosion (Table 3). A sieve analysis was completed by weighing the samples, then processing the mineral soil through a series of nested sieves (see Table 11). A pan at the bottom of the stack collected the fines. The column of sieves was placed in a mechanical shaker (W.S. Tyler, model ROTAP R1-29) and processed for ten minutes (USDA NRCS, 2004). After the shaking was complete the material retained on each sieve was collected and weighed. The weight of the sample

Table 11

Sieve numbers and sizes used for coarse-textured sediment content analysis.

Sieve Number	Sieve Opening (mm)	Textural Class of Material Retained
1 1/4”	31.5	Gravel
5/8 “	16	Gravel
5/16”	8	Gravel
5	4	Gravel
10	2	Gravel
18	1	Very Coarse Sand
35	0.5	Coarse Sand
60	0.25	Medium Sand
120	0.125	Fine Sand
230	0.0625	Silt and Clay
Pan	None	Remaining Fine Sized Particles

retained on each sieve was then divided by the total weight to give a percentage for each particle size. After the material from each sieve was weighed, all materials larger than 2 mm were set aside and the remaining, smaller materials were saved for the fine-textured sediment analysis.

Fine Textured Sediment Analysis

Fine textured sediment analysis describes the proportion of sand, silt and clay particles to the overall sample of soil. Fine textured soils tend to be moist, have poor aeration and drainage, and are susceptible to compaction (Table 3). This procedure differs from the coarse textured analysis as the sieving process identifies particles up to 0.0625 mm; however, the fine textured analysis can identify the distribution of particles up to a size of 0.001 mm (ASTM Standard D-422, 2007). Once the proportion has been identified, the standard soil textural triangle is used to determine the textural class of the sample. Fine textured soils tend to be moist, moderately organic soils that are highly susceptible to compaction (Table 3).

Soil texture by hydrometer is a primary method used in soil science for particle size analysis (Gee & Bauder, 1979). This method quantitatively determines the proportions of sand, silt and clay particles (<2 mm) based on Stokes Law, which describes the settling rates of suspended solids in solution using a hydrometer (Gee & Bauder 1979; Bouyoucos, 1962). To achieve this, 50g of dry screened soil was placed in the hydrometer cylinders with 125 ml of the dispersing agent and let stand overnight. The dispersing agent was comprised of 40 g of sodium hexametaphosphate per liter of distilled water and prepared twenty four hours before use (ASTM D422, 2007). After the 50g soil samples and dispersing agent soaked for approximately sixteen hours, the slurry was transferred to a metal dispersion cup then agitated in a soil mixer for a period of 3 minutes.

The solution was transferred back into the hydrometer cylinder and filled with distilled water to the 1000 ml mark, then manually agitated for another sixty seconds by turning the cylinder upside down and back upright repeatedly approximately 30 times. After the sixty second manual agitation period, the cylinder was set down and the time was recorded on the data sheet, and a thermometer was inserted by suspending it from the top of the cylinder. Thirty seconds after agitation, the hydrometer was inserted into the cylinder and a reading was recorded at precisely forty seconds. The reading was taken by observing the top of the meniscus that extends vertically from the hydrometer stem, above the surface of the soil-distilled water mixture. Subsequent hydrometer and temperature readings were taken at 2, 7, and 24 hours and each reading was adjusted to account for temperature differences, i.e., for each degree Celsius above eighteen, 0.25 g/L was added to the original hydrometer reading. Using the 24 hour data for clay, the resulting data was compared to the standard soil textural triangle to identify the overall texture for each sample. Once the texture was determined, I used the Kruskal-Wallis analysis of variance test to analyze the relationship between the textural class and the change of campsite impact between 1985 and 2008 (McGrew & Monroe, 2000).

Soil Moisture Content

The relationship between soil moisture and recreational impacts depends upon compaction rates, campsite slope and aspect, soil texture, organic content and other factors. Other variables aside, an inverse relationship usually exists between compacted soils and moisture content (Hammitt & Cole, 1998). In general, soil moisture tends to decrease as compaction increases due to reduced infiltration and increased runoff (Figure 6). Moderate soil moisture is ideal in campsites, as it promotes plant growth without the negative characteristics of excessively wet soils (Hammitt & Cole, 1998).

Field collected soil samples were stored in two, sealed plastic bags for approximately 6 months prior to laboratory processing. Soil moisture was assessed by the gravimetric method. Soils were weighed before and after the drying process to accurately determine the moisture content of each sample. Samples were processed in a Sheldon VWR International drying oven (model 1320) at temperature of 105°C for 24 hours in order to eliminate hygroscopic water and water of hydration from minerals (USDA NRCS, 2004; Day, 1965). Excessive heating was avoided as it may lead to weight loss associated with compromised carbonates. Results were statistically analyzed using the non-parametric Mann-Whitney *U* test which determines the ranks of sample observations to measure the magnitude of differences between the two sets of sample data, grouped by control samples and campsite samples (McGrew & Monroe, 2000).

Organic Matter Content

Recreational foot traffic tends to reduce organic matter quickly. As foot traffic moves over the organic horizon, the litter is scuffed and broken into smaller pieces which are easily eroded from the site, leaving the mineral soil vulnerable to compaction and unable to hold rainwater or feed soil organisms (Hammitt & Cole, 1998). I measured organic content with the Loss-On-Ignition (LOI) method (USDA NRCS, 2004b). This method estimates organic matter by calculating the loss of mass that results from the ignition of organic matter in a high temperature oven. To achieve this, the oven-dried sample was weighed to determine the overall mineral and organic weight prior to LOI processing. Once weighed, the samples were transferred into graphite crucibles and processed in a Muffle furnace (Barnstead Thermolyne, model 6000) for sixteen hours at 400°C to ensure that organic matter was destroyed (USDA NRCS, 2004b). Once the processing was complete, samples were weighed again. The difference between the first weight and the second weight determined organic loss. Results were statistically analyzed by using the Kruskal Wallis analysis of variance comparing soil organic content with the BMREP impact rating, and the Mann-Whitney *U* test comparing soil organic content with soil moisture (McGrew & Monroe, 2000).

Soil pH Analysis

Measuring soil pH is one of the best methods to pinpoint soil chemical properties (McLean, 1982). Soil pH is influenced by the parent material, amount of weathering, and oxidation of organic matter. The acidity, neutrality, and alkalinity affect the ability of plants to process nutrients from the soil (McLean, 1982). Samples were analyzed in the laboratory by mixing previously unprocessed soil samples and distilled water at a 1:1 ratio, then measured with a Hanna Checker pH meter (model HI 98103) capable of frequent calibration tests to assure accuracy (USDA NRCS, 2004a). Results were statistically analyzed by using the Kruskal Wallis analysis of variance comparing soil pH with the BMREP impact ratings, and Spearman's Rank Correlation test comparing soil pH with soil moisture (McGrew & Monroe, 2000).

Soil Compaction

Campsite compaction was measured in order to compare the compaction rates of the impacted campsite areas with areas outside of the impacted core. This analysis helped determine if campsites have increased bulk density. Soil compaction was measured in the field by using a drop cone penetrometer to estimate surface soil strength. The drop cone technique is rapid and precise, allowing many samples to be obtained in a short period of time (Jones & Kunze, 2004). This method consists of releasing a weighted (2 kg), apex angle cone from a height of one meter through a rigid cardboard tube set perpendicular to the soil, and measuring its depth of penetration to the nearest centimeter. A transect was placed through the center of the campsite along the north to south axis. Measurements began 1 m outside of the impacted parameter, at each 1 m interval along the north to south axis running through the campsite, and the final measure was recorded 1 m outside of the impacted area on the opposite side of the campsite. Five compaction measures were recorded at each 1 m interval, then averaged to obtain a compaction measure for each point. (i.e., a 10 m transect would include 50 independent compaction measures). Results of the measures taken outside of the impacted area were compared with the resulting data from inside the campsite using the Wilcoxon Signed Rank statistical test, which tests the hypothesis that the frequency distributions between the two sets of sample data are identical (McGrew & Monroe, 2000).

Comparing 2008 Results with 1985 and 1988 Data

To assess the change of impacts at campsites adjacent to Waptus Lake between 1985 and 2008, I used the Kolmogorov-Smirnov Two Sample Test (McGrew & Monroe, 2000). Due to the similarities between the WROS system and the BMREP, these comparisons can be made with statistical precision.

Document Changes in Trailhead Use over Time

To address the question relating to change in trailhead use between 1996 and 2008, I used a systematic random sample (K = N/n) design to obtain a 25% sample of permit stubs for each year (Watson, Cole, Turner, & Reynolds, 2000). The first step was to hand count permit stubs for 1996-2008 to determine the accurate number in each year, and then select every fourth sample until 25% sample size was collected for each year. Once the samples were obtained, I entered the user data into an Excel spreadsheet to create the data set. To analyze the change of user numbers at the Salmon La Sac Trailhead, I used the Spearman Rank Correlation (r_s) statistical test to measure the strength of association between years and trailhead use (McGrew & Monroe, 2000).

The next statistical analysis assessed the relationship between the numbers of packstock per person and wilderness trip duration over time. To do this, I isolated three variables (duration, group size, and stock) from each year of the wilderness permit data set. I combined the data from 1996 – 2008 into a new data set, then reclassified each variable based on value (see Table 12) to create a frequency which allows us to test the statistical relationship between the classification systems. In order to test the relationship between the number of packstock per person and wilderness trip duration, I used the Chi-Square Goodness-of-Fit statistical test (McGrew & Monroe, 2000). This test is used to analyze tables of discrete data. Once the Chi-square value was determined, I used the Cramer's v coefficient to test the strength of the Chi-square statistic (McGrew & Monroe, 2000).

Table 12

Packstock Use Characteristics Reclassification System

Duration of Trip	1	2 or 3	> 4
Reclassification	1	2	3
Group Size	1	2 or 3	> 4
Reclassification	1	2	3
Number of Stock	1	2 or 3	> 4
Reclassification	1	2	3

Provide Management Recommendations

Wilderness managers are constantly tasked with making decisions that protect the resource elements while respecting the Wilderness Act by keeping human intervention to a minimum. Since managers intervene in ecosystem processes regularly (Cole & Yung, 2010), it is important that proactive wilderness management mimics natural processes and minimizes the negative impact associated with visible human intervention.

The broad-based ALALMP was finalized in 1981. While this document sets minimum requirements for wilderness campsites, most area-specific management plans and recommendations are lacking. Herman’s 1988 report does include use pattern observations and provides a few management suggestions, most in regard to stock use. However, a specific Waptus Lake management plan does not exist despite the impact monitoring efforts conducted in 1985 and 1988.

A final outcome of this research involved working with local and regional Ranger District staff to develop study site management recommendations within the guidelines of the applicable management plans. Together, we examined a variety of management options, including partial site closures, moving campsites for setback compliance, visitor and stock limitations, identifying specific “zones of impact”, and modifications to existing plan standards (Table 8). Management recommendations for Waptus Lake were based on a review of literature, applicable management plan documents, and conversations with Ranger District staff. Suggestions include frequency of monitoring, user education strategies, closure and active intervention for specific sites, and future research opportunities.

CHAPTER V

RESULTS AND DISCUSSION

Spatial Patterns of Campsites

Spatial Distribution of Campsites

A total of 42 active and abandoned campsites were identified in the study area in 2008 and 2009. Of these, 32 were active and 10 were abandoned. Of the active sites, 24 were lake sites, eight were trail sites and 30 of the 32 identified were present in 1985, although one (WAL31) was assessed for impacts in 1985, but considered part of site WAL 10 and not assigned a number or monitored in 1988. Site WAT 26 was not assessed in 1985, and was not monitored in 1988, but it was identified on Herman’s map as an unmonitored site (Figure 5). Site WAL 32 was the only newly established campsite identified in 2008. The majority of abandoned campsites seemed to fall out of use due to the blow down of large diameter trees through the center of the campsites.

The spatial distribution of campsites (see Figures 15, 16, 17, 18 & 19) revealed what the literature predicted about campsite dispersal. Most of the campsites are clustered around the prime destination (Hammitt & Cole, 1989), in this case the North and Southeast shores of Waptus Lake. These findings were expected, as the study site is a popular lake. The campsite locations also seemed to reflect the three-stage choice model (Table 1), of evaluating sites based on necessity, experience, and amenity attributes (Brunson, 1989). Using this model, visitors first consider whether potential sites have "necessity attributes" which meet basic camping needs. The campsites that have the necessity attributes are then evaluated for "experience attributes" such as good views and

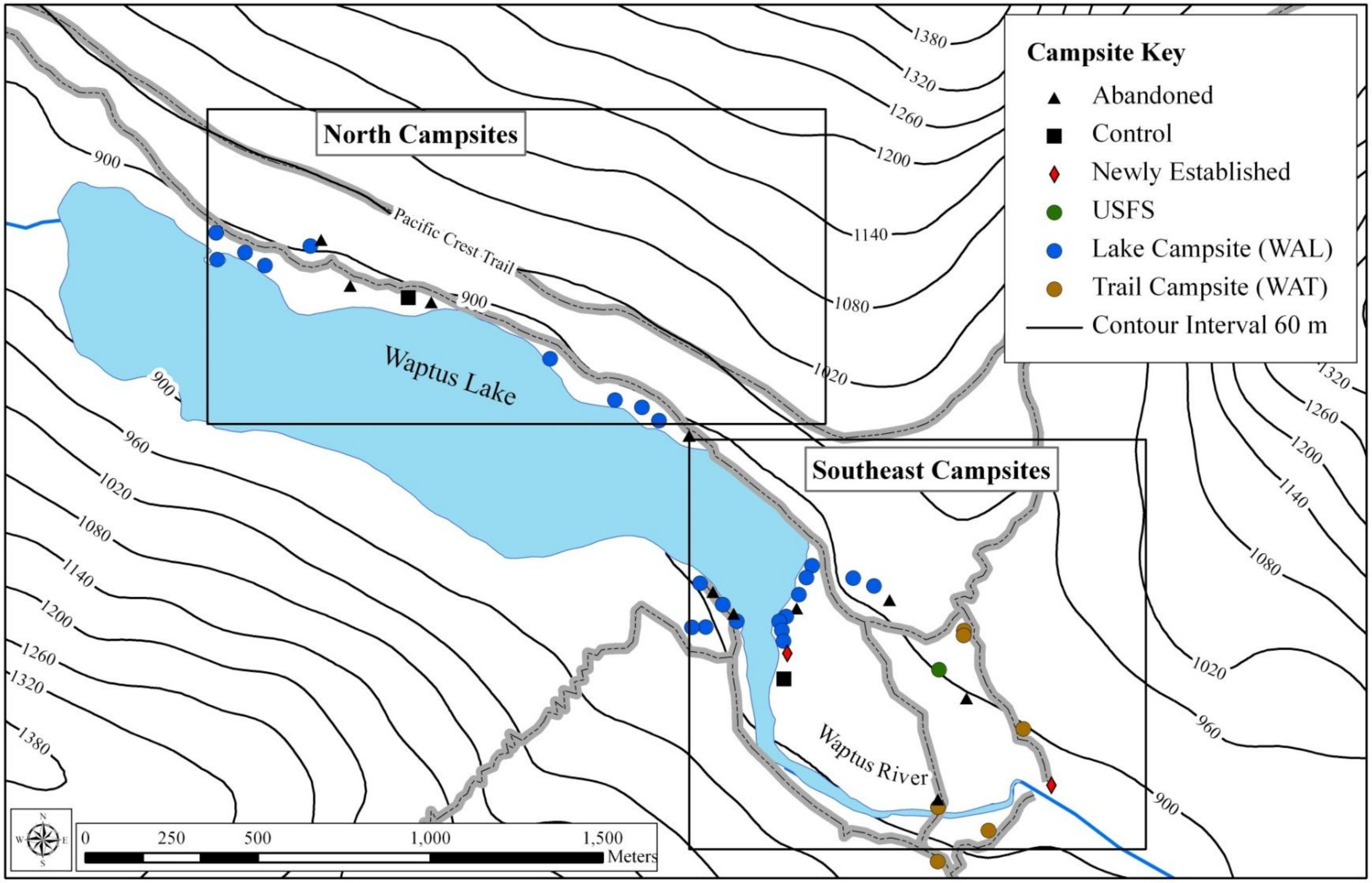

Figure 15. Waptus Lake campsite locations as of 2008

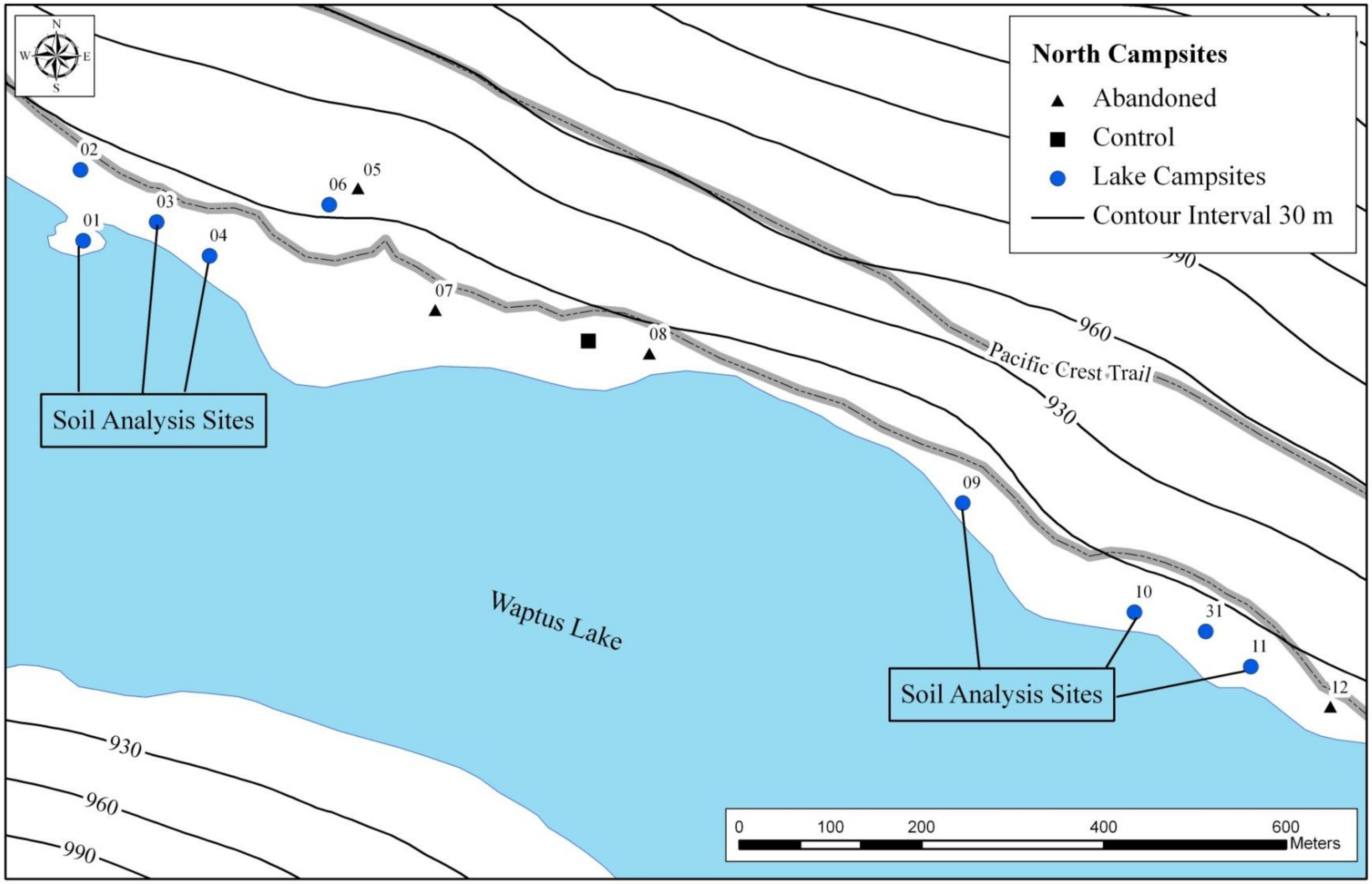

Figure 16. North Waptus Lake campsite locations as of 2008.

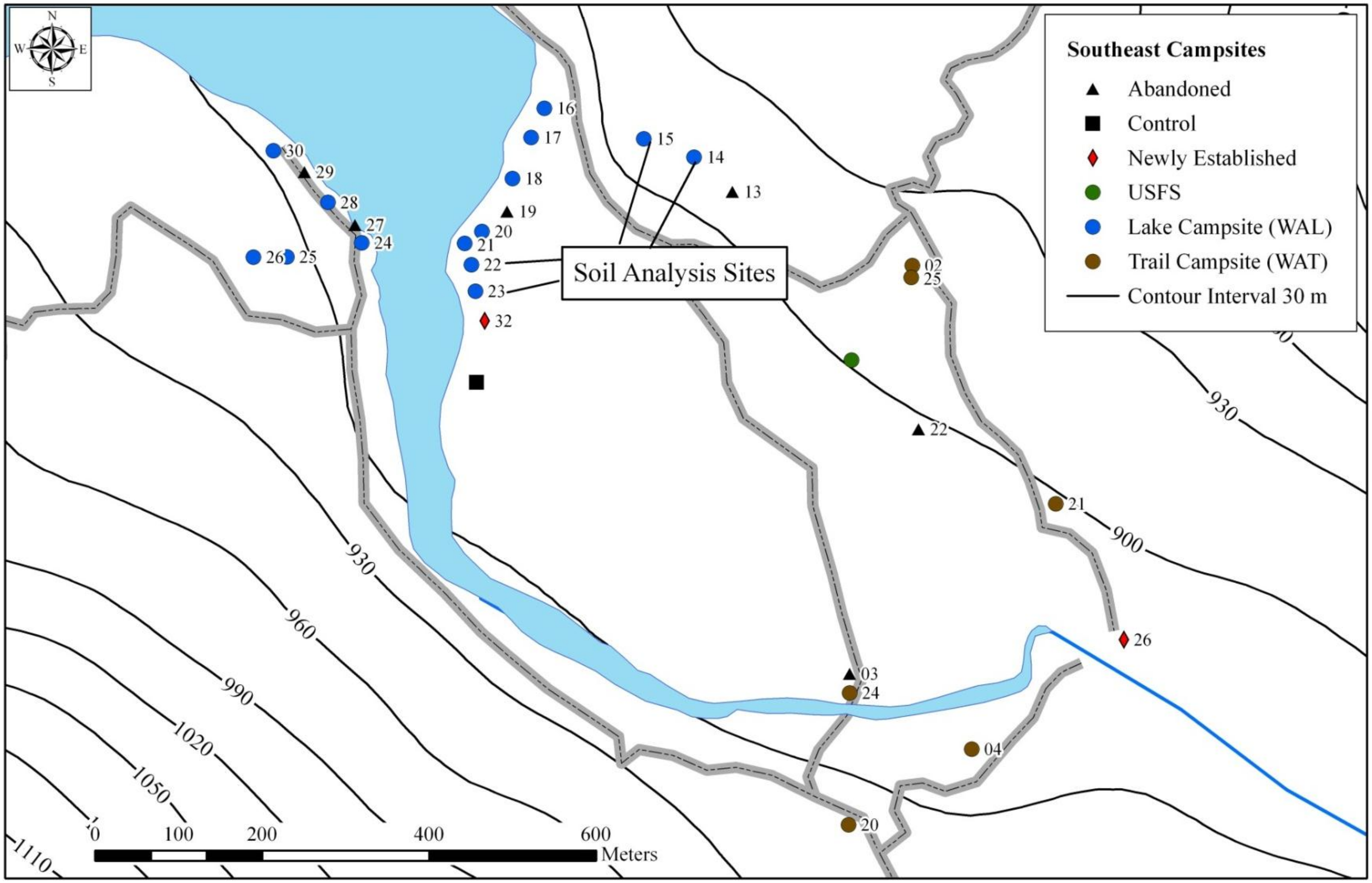

Figure 17. Southeast Waptus Lake campsite locations as of 2008.

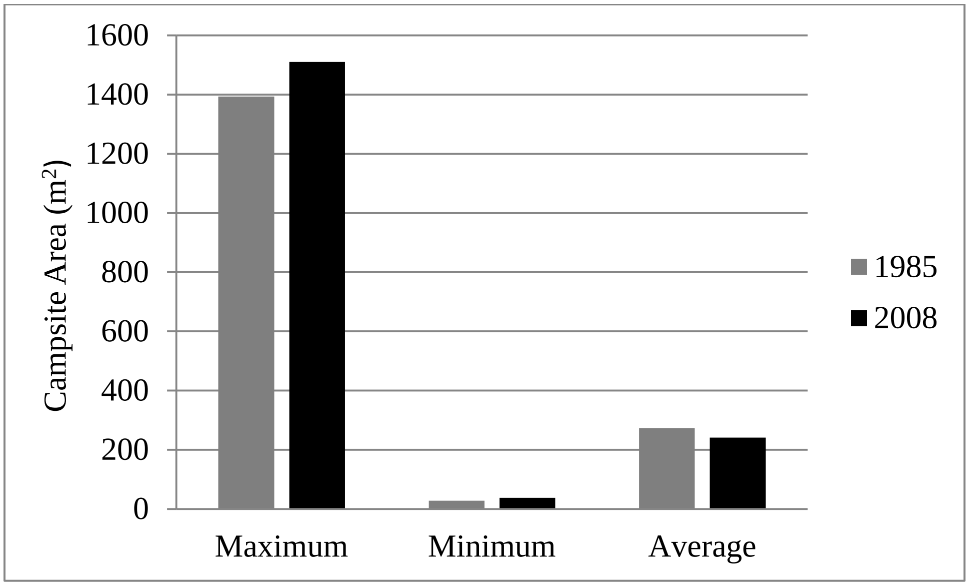

Figure 18. Campsite area spatial patterns, 1985 & 2008.

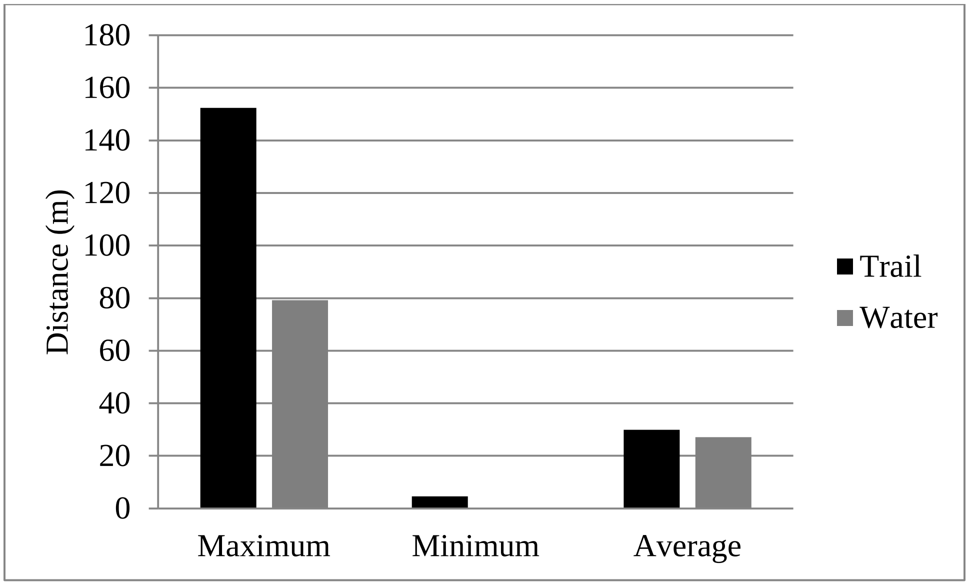

Figure 19. Campsite distance to trails and water, 1985 & 2008.

privacy. "Amenity attributes" are considered in the final stage, focusing on aspects such as access to good fishing holes, or desirable amounts of sun or shade (Brunson, 1989).

The scope of this research did not include site selection interviews with visitors; instead, this conclusion is based upon generalizations of campsite attributes with impact.

Individual Campsite Areas

Individual campsite areas, on average were approximately 241.1 m^2, or six times the maximum size allowed in the ALALMP. The smallest campsite, WAL 9, was 37.2 m^2, which is the maximum allowable campsite size (Figures 16 & 18). The largest campsite, WAL 17, was 1,510.2 m^2 or over forty times the maximum campsite size. Overall, 31 of 32 active campsites were out of compliance due to size (see Appendix D for complete data).

Significant compliance issues were found in regard to the management directive regarding setbacks from water and trails, with many campsites located immediately adjacent to these attributes. Five of the 32 active campsites complied with the 61 m setback from water, and only two of the active campsites met the setbacks from trails. The maximum and minimum distance from water was 79.2 m and 0.0 m, respectively, with an average campsite distance from water at 27.1 m. The maximum and minimum distance from trails was 152.4 m and 4.6 m respectively, with an average distance of 29.9 m (Figure 19).

While one campsite met the maximum size requirement, none of the lake campsites met both the size (37.2 m^2) and the setback requirement of 61 m (Figure 19. Each of the lake and trail campsites monitored was found to be out of compliance with the ALALMP due to their size exceeding the 37.2 m^2 maximum or due to their location within the 61 m limit of trails, meadows, Waptus Lake, and area streams (USFS, 1981).

Biophysical Condition of Campsites

Bob Marshall Rapid Estimation Procedure

The BMREP assessed the condition of all active campsites during the 2008 field season (see Appendix E for complete data). Results indicated that out of the 32 active campsites; 12 campsites experienced improved conditions compared to 1985 data, 16 had no change of impact; and one campsite experienced worsened conditions (WAL 31). Two campsites had new impacts (WAL 32 & WAT 26), and one campsite was not monitored (USFS Camp). Of the active campsites in 2008, 38.7% had a "severe" impact rating, 41.9% had a "heavy" impact rating, and 19.4% had a "moderate" impact rating (see Figure 20). No campsites were rated "light" (Figures 21 & 22). An additional 10 campsites were located, but determined to be abandoned. Seven of the established campsites from 1985 were abandoned in 2008 and the two newly established campsites have quickly reached the "severe" level of impact as of 2008 (Figure 21).

In 1985 the majority of campsites (68.4%) adjacent to Waptus Lake were rated as "severe." Duplicate measures in 2008 demonstrated a drastic improvement in campsite ratings, with the "severe" rating dropping to 38.7% and the improved campsites reclassified to a lower "high" or "moderate" rating (Figures 21 & 22). Using the Kolmogorov Smirnov statistical test, campsite impact was found to be significantly different between 1985 and 2008 (D= 0.06, p= 0.0001). Since the sample size was larger than 40, the critical value of D was calculated (a = .025). This difference was confirmed using Wilcoxon Signed Rank to evaluate differences between 1985 and 2008 impact data. The results indicated a significant difference, z = 1.95, p = .0.057.

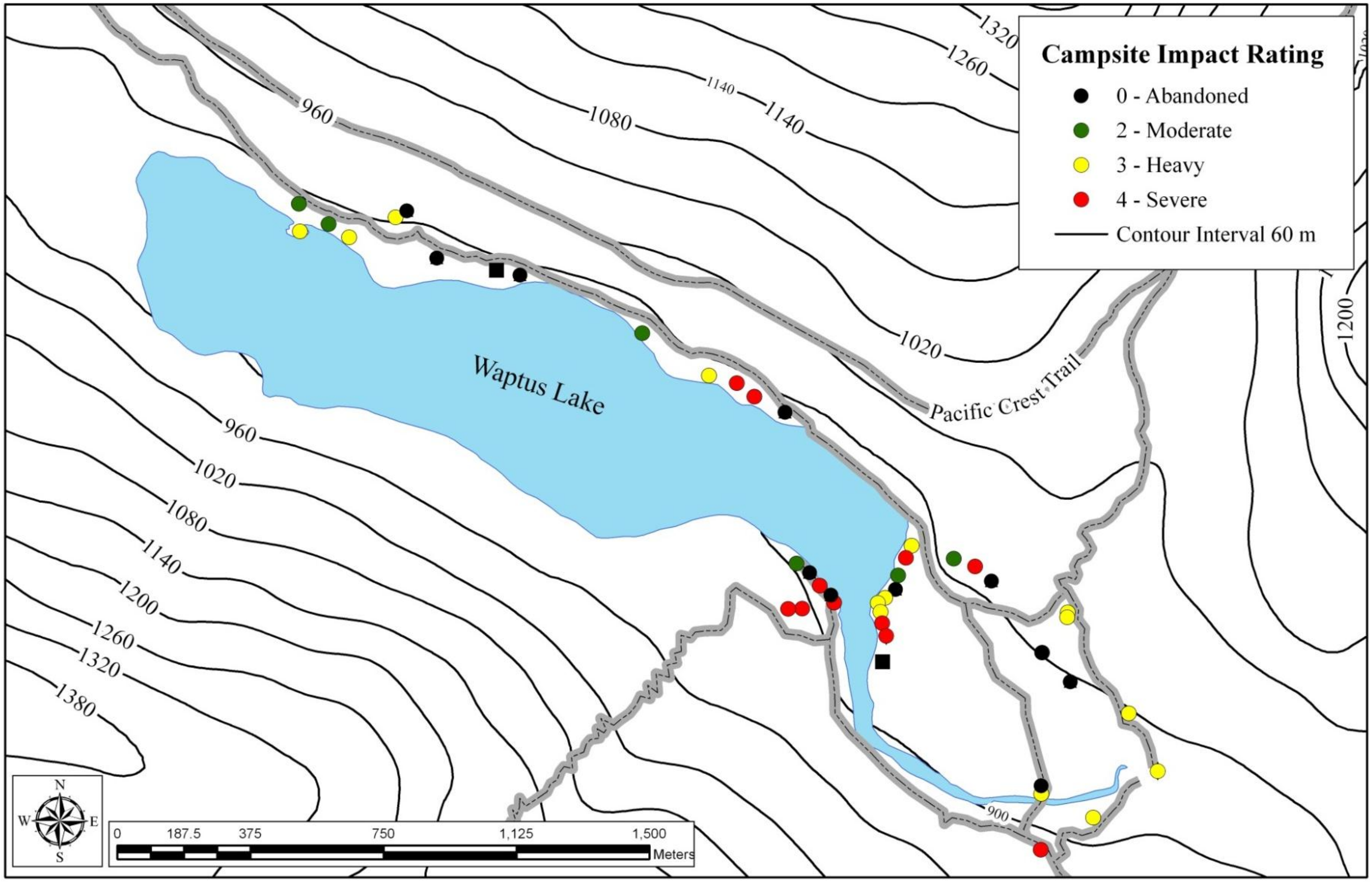

Figure 20. Bob Marshall Rapid Estimation Procedure results for Waptus Lake campsites as of 2008.

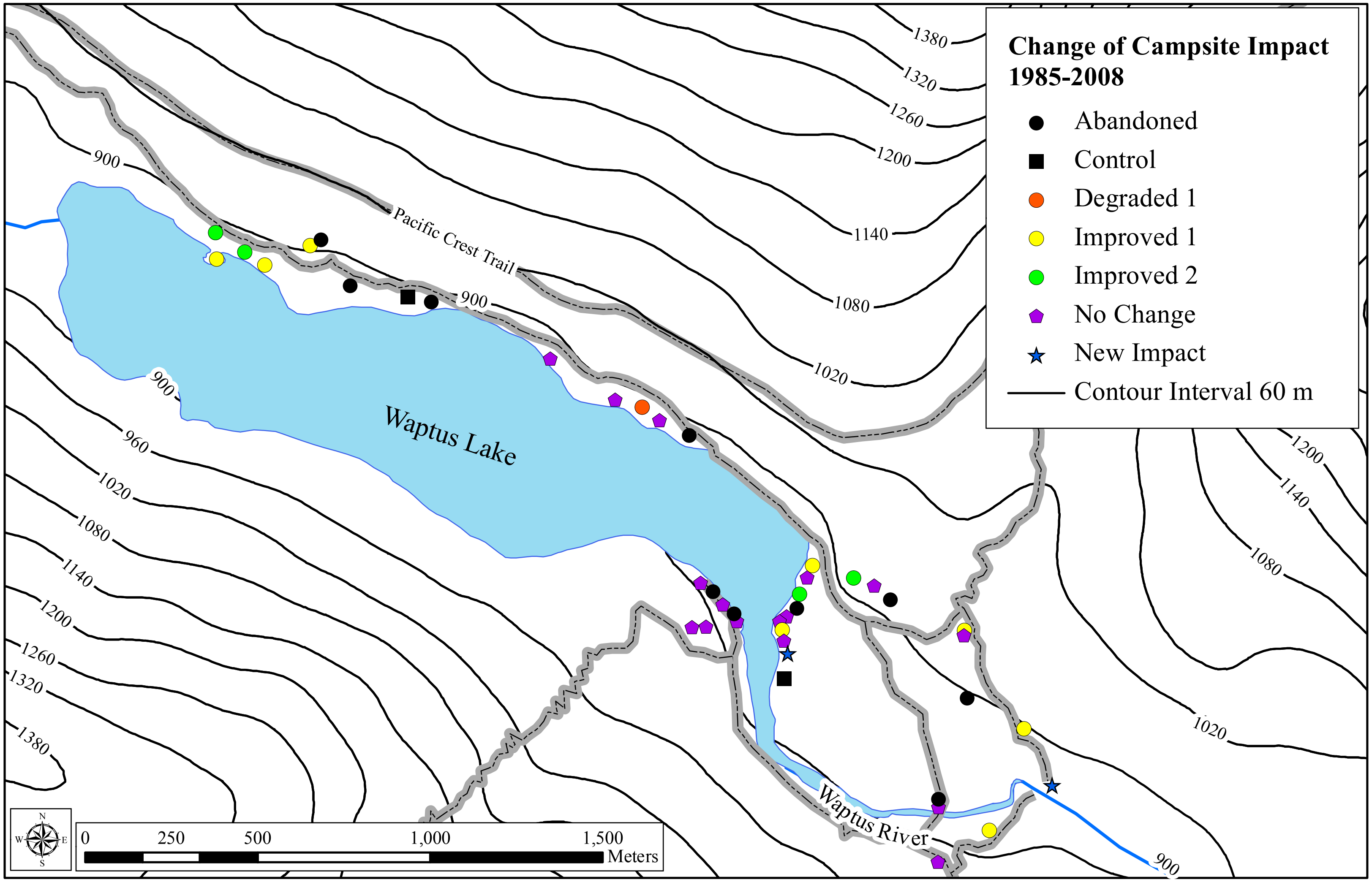

Figure 21. Waptus Lake campsite impact ratings comparing the 1985 Recreational Opportunity Spectrum with the 2008 Bob Marshall Rapid Estimation Procedure.

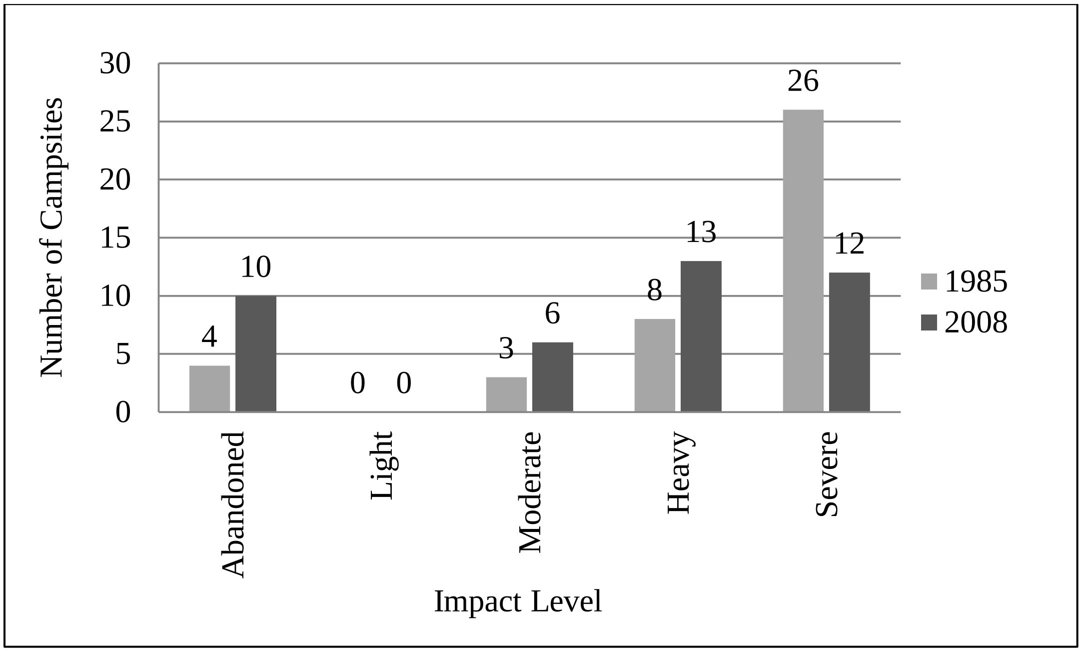

Figure 22. Waptus Lake campsite impact ratings, 1985 and 2008.

The campsite impact improvements are likely due to at least three factors. The most obvious is the decline in use of the Waptus Lake trailhead between 1996 and 2008. A number of campsites were rendered totally unusable due to natural processes such as tree fall or creek washouts, as is the case with sites WAL 07, WAL 19, and likely the case with WAT 01, WAL 08, and WAL 27. The 1981 policy change requiring packstock to be tethered at least 61 m away from water likely contributed to campsite improvement (USFS, 1981). This simple policy adjustment removing packstock from the campsites adjacent to the lake greatly reduced the levels of soil compaction, vegetation trampling and grazing, and tree damage from tethering (Cole et al., 2004). Seasonal climate variations represent an additional factor that could have an effect on impact ratings between 1985 and 2008. A review of historic climate data revealed that 1985 had the warmest and driest moth of July in comparison to other years from 1971 to 2000. In comparison, July of 2008 had more precipitation and cooler temperatures (see Figure 23, WRCC, 2010).

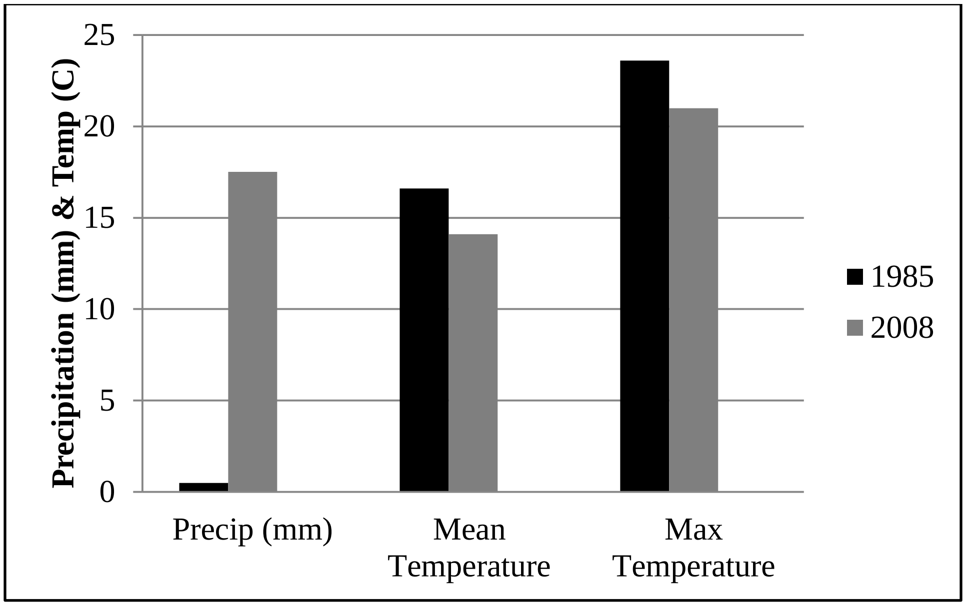

Figure 23. Comparison of Stampede Pass climate data for 1985 and 2008.

Repeat Photography

Photo points for each campsite were replicated as a tool for documenting changes in vegetation and spatial patterns within each campsite (Appendix A). Prints of the 1988 photo points when used along with Herman's 1988 campsite maps were a valuable tool for helping to locate campsites, especially those that were since abandoned. The photo points were also useful in identifying changes in the campsite perimeter that are not adequately addressed when only using the impact rating sheets. The limitations of repeat photography include the challenges associated with replicating a 20-year old photograph with different technology, lighting and weather conditions. The resulting photographs are difficult to analyze quantitatively and are limited to qualitative analysis.

A visual assessment of the 1988 and 2008 of photographs found the majority of campsite conditions to have slightly improved or to have shown no discernible change. Figure 24 displays the result of comparing 1988 photographs with duplicates taken during the summer of 2008. A few campsites significantly improved, while most of the sites slightly improved or showed no discernible change. Two images showed instances where conditions have slightly degraded, and none of the campsite images demonstrated conditions that have significantly worsened (see Appendixes, B, C, G & H for complete data).

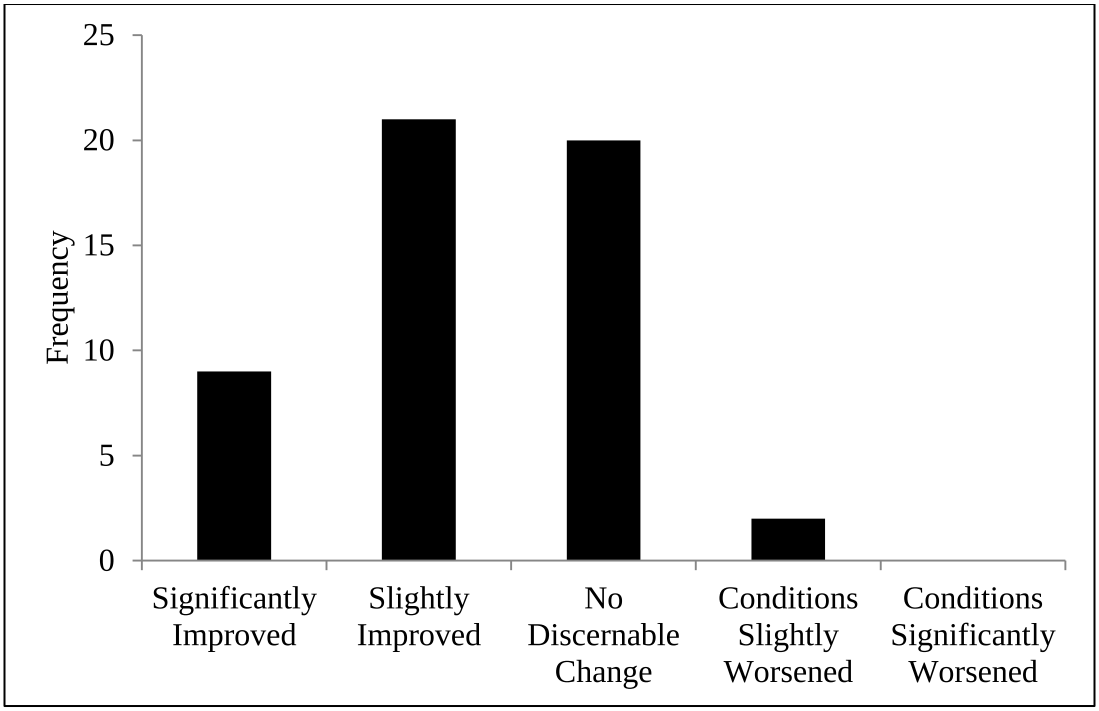

Figure 24. Campsite impact change by visual assessment of repeat photography.

Repeat photography of campsite 18 provides an example of this method illustrating a change in spatial patterns (see Figures 25 & 26). The photo in Figure 25 depicts the campsite in 1988 and shows a large, heavily impacted campsite. Impact data sheets from 1985 indicate the campsite size to be 223 m^2, and the 1988 hand drawn map associated with this campsite indicates the barren core and area of denuded vegetation to total an impact of 261 m^2. Field notes recorded in 1988 indicate that the size has expanded significantly over the past few years.

The photograph in Figure 26 was taken from approximately the same point in 2008. It is clear that the site has experienced a noteworthy reduction in spatial extent during this 20-year period. In Figure 25, the site sprawls into the background, while in Figure 26 the area in the background is showing recovery. Field-collected data confirms there has been a reduction in size. While 1988 measures of barren core and the area of denuded vegetation totaled 261 m^2, 2008 measures totaled only 167 m^2.

One potential reason for this 64% reduction in the spatial extent of the site may be due to tree fall. Figure 25 shows a large diameter tree fallen across the campsite, essentially creating a new campsite boundary and microenvironment assisting seedling establishment. Campsite 18 was one of the campsites that experienced a substantial BMREP rating improvement (Table 15), which was primarily due to the reduction of size.

Figure 25. Campsite 18 in 1988, measuring 261 m^2.

Figure 26. Campsite 18 in 2008, measuring 167 m^2.

Repeat photography of campsite 10 provides an example of this method illustrating changes in campsite impact that are not quantified using the BMREP (see Figures 27 & 28; Brewer & Berrier, 1984). The 1988 photo in Figure 27 depicts a large campsite with impacted vegetation between the campsite and the lake. Figure 28 was taken from approximately the same point in 2008. This image shows substantial vegetation recovery between the campsite and the lake. This recovery in the vegetation buffer is likely due to the requirement of tethering packstock 61 m from the lake. Coincidentally, like campsite 18, tree fall probably played an important role in this change. Figure 27 shows a large diameter tree had fallen within the campsite, across the vegetation between the campsite and the lake. Figure 28 shows that tree had diminished from rot, but was in the same location twenty years later. According to the BMREP results, this campsite did not experience a change in level of impact between 1985 and 2008, but the vegetative recovery adjacent to the campsite is a positive change. The likely reason that this change was not captured by the BMREP is the method focuses on the impacted area of the campsite in comparison with a relatively undisturbed control area. A weakness of the BMREP is the failure to address the changes in campsite buffer zones.

Figure 27. Campsite 10 in 1988 with impacted vegetation buffer.

Figure 28. Campsite 10 in 2008 with a recovering vegetation buffer.

Site Specific, Detailed Measurements

This relationship was assessed by analyzing forty-eight samples from ten campsites and two control sites (Figures 15, 16, & 17; Appendix F).

Coarse Textured Sediment Contents

Results of the sieve analyses indicate wide variability amongst soil particle size distribution with a general trend of coarse, sandy soils among the North campsites, and fine textured soils among the Southeast campsites. North campsites averaged 13.3% gravel, 52.4% sand, and 34.3% mud (see Figure 29). Southeast campsites averaged 4.8% gravel, 42.0% sand, and 53.3% mud (Figure 29). In general, the North campsite soils contained more gravel and sand than the southeast soils. This finding is logical since the North campsites are spodosols on alluvial fans comprised of coarse, sandy textured soils (Buol et al, 2003). In contrast, the Southeast campsite soils comprised of inceptisols in glacial moraine deposits (Wolcott, 1973) averaged 19% more mud, or fine sediment than the north shore. This findings support literature regarding inceptisols, particularly the extent of the soils found in areas of glacial deposits (Buol et al., 2003).

When examining the results for individual campsites, two broad categories emerge based on the overall percentage of fine particles under 0.0625 mm. Campsites WAL 3, 14, 15, 22 and 23 had large quantities of fines (< 0.0625 mm) ranging from 46.6% to 57.9% (see Figure 30). Each of these samples also had a very small percentage of gravel material (2.4% - 8.2%, respectively). According to the physical properties of soil based on particle size distribution, these sites may be slightly more susceptible to compaction than the remaining five, which had a greater diversity of grain size

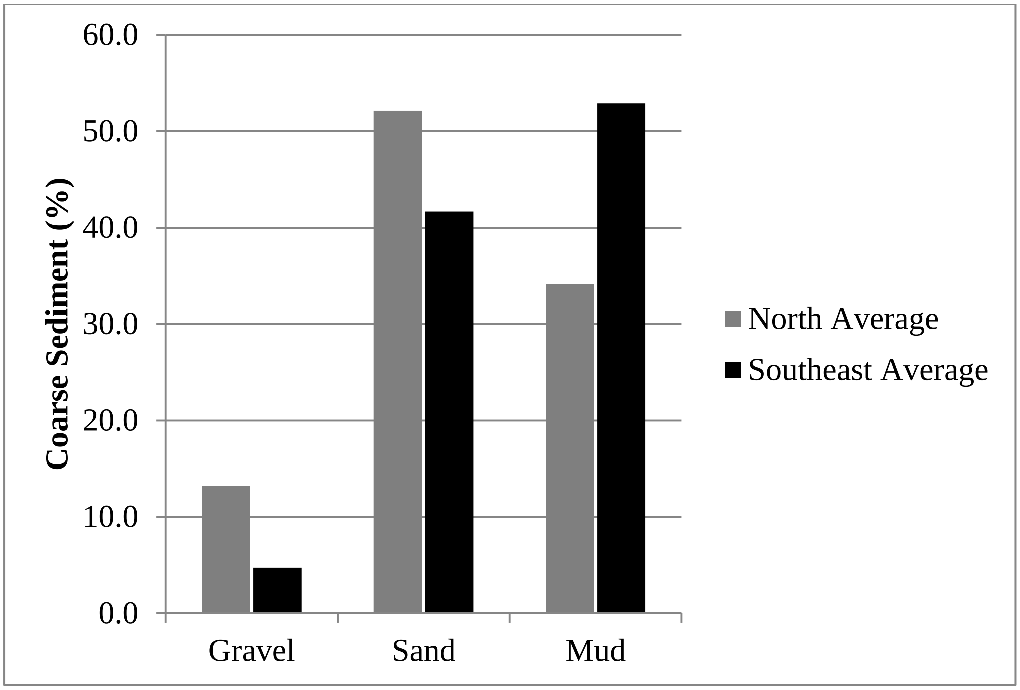

Figure 29. Waptus Lake coarse sediment results averaged by area.

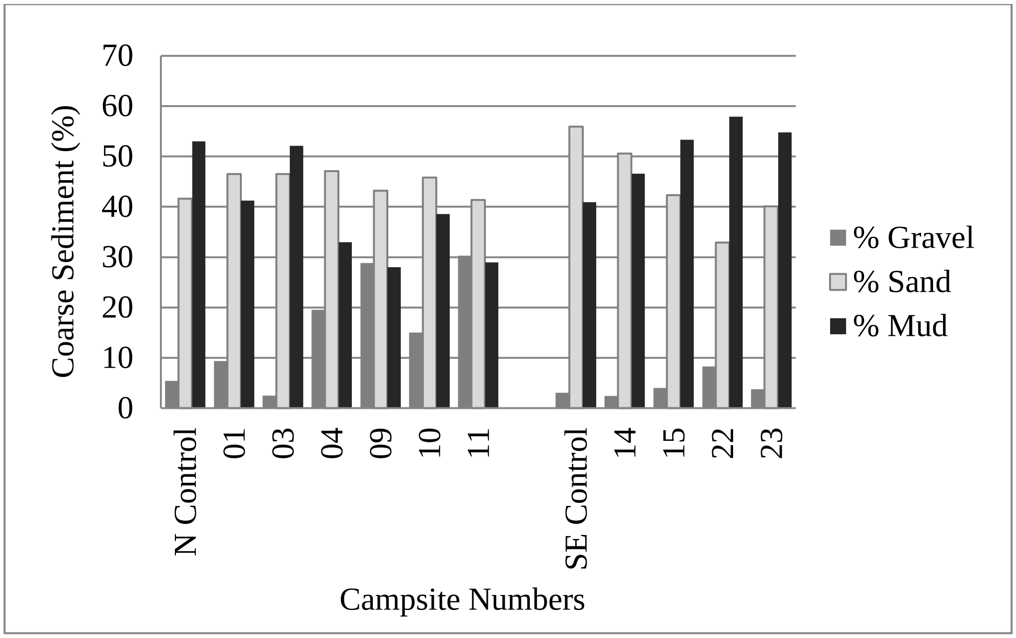

Figure 30. Waptus Lake campsite specific coarse textured sediment content.

Table 13

Descriptive Statistics for Coarse Textured Sediment Content

Parameter	North shore campsites	North shore control	Southeast shore campsites	Southeast shore control
Sieve Analysis				
Gravel				
Median	14.4	2.6	3.6	2.8
Maximum	58.6	16.5	18.4	5.1
Minimum	0.0	0.2	0.1	1.9
Interquartile range	58.6	16.3	18.3	3.2
Sand				
Median	46.6	40.1	40.3	55.6
Maximum	89.4	47.4	51.1	61.4
Minimum	26.6	38.9	24.2	51.2
Interquartile range	62.8	8.5	26.9	10.2
Mud				
Median	30.2	53.4	50.2	41
Maximum	56	61	74	46.3
Minimum	10	44.2	40.6	35.5
Interquartile range	46.4	16.7	33.4	10.8

distribution, with a higher representation of particles over 0.0625 mm. With the exception of site 3 and arguably site 1, the Vabus soils on the North shore of Waptus Lake had a closer to even grain distribution compared to the Kladnick soils on the Southeast shore. A comparison of medians confirms the variation between the North and Southeast campsite soils (see Table 13), this difference was also confirmed by statistically comparing the interquartile range for coarse textured sediment content (Mann-Whitney $U = 9.0$, $p = 0.1$, two-tailed test). The descriptive statistics also show that the control sites are not representative of the general campsite areas in regard to texture.

Fine Textured Sediment Content

The results of the hydrometer analyses (see Figure 31) revealed two primary textural classes represented at Waptus Lake. The dominant textural classes of the samples were loams and sandy loams, with loams primarily in the Southeast campsites, and sandy loams in the North campsites. This finding generally supports the results of the coarse texture analysis. Of the larger pool of samples, clay loam, silt loam, and sandy clay loam were also represented (Figure 31). Soil texture may affect campsite impact recovery because fine textured soils tend to be moist with poor aeration and drainage, while coarse soils have good aeration and drainage, their capacity of holding water, supplying nutrients, and organic matter is low (Table 3; Brady & Weil, 2008).

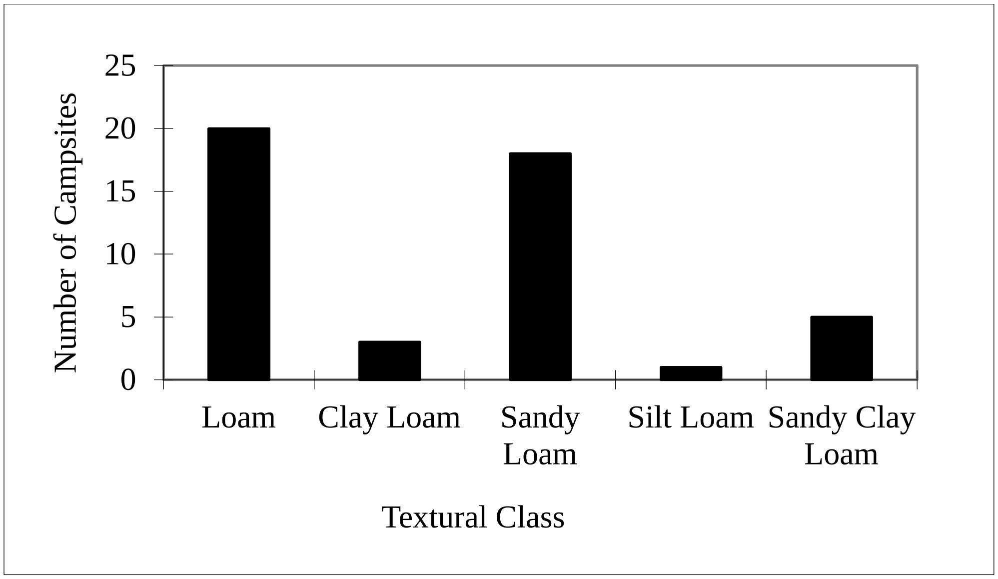

Figure 31. Waptus Lake fine soil texture distribution

Statistical analysis revealed a significant relationship between soil texture and impact change for the campsites that improved by one BMREP impact class (Kruskal-Wallis, *p* = 0.03), suggesting that different soil textural classes may support impact recovery at faster rates than others (Brady & Weil, 2008). However, there did not appear to be a relationship between the soil order and BMREP impact ratings (Kruskal-Wallis, $p = 0.14$). Since multiple parameters beyond soil and vegetation conditions contribute towards the overall BMREP impact rating, I suspect the statistical significance is also based on other campsite conditions such as overall size, number of social trails, cleanliness and other parameters (Appendix B).

The results of the coarse and fine texture analysis are of note because the soils most susceptible to compaction when moist are sandy loams, sandy clay loams, and loamy sands. The soils less susceptible to compaction are silty clays, clays, and fine sands (Kuss, 1986). These different soil types may respond very differently to campsite restoration efforts. It is likely that the less compact, coarse soils along the North shore would respond well to recovery efforts, while the fine textured soils along the Southeast shore would respond at a slower rate and require intervention, such as scarification, addition of organics, and seeding (Table 2; Cole & Spildie, 2007).

Soil Moisture

Laboratory results of soil moisture showed high variability among the 48 individual samples; however, once averaged the results showed more consistency (see Figures 32 & 33). Campsite moisture content on the north shore averaged 22% compared to 25% moisture on the control site. In contrast, southeast campsites averaged 19% compared to 14% on the control site.

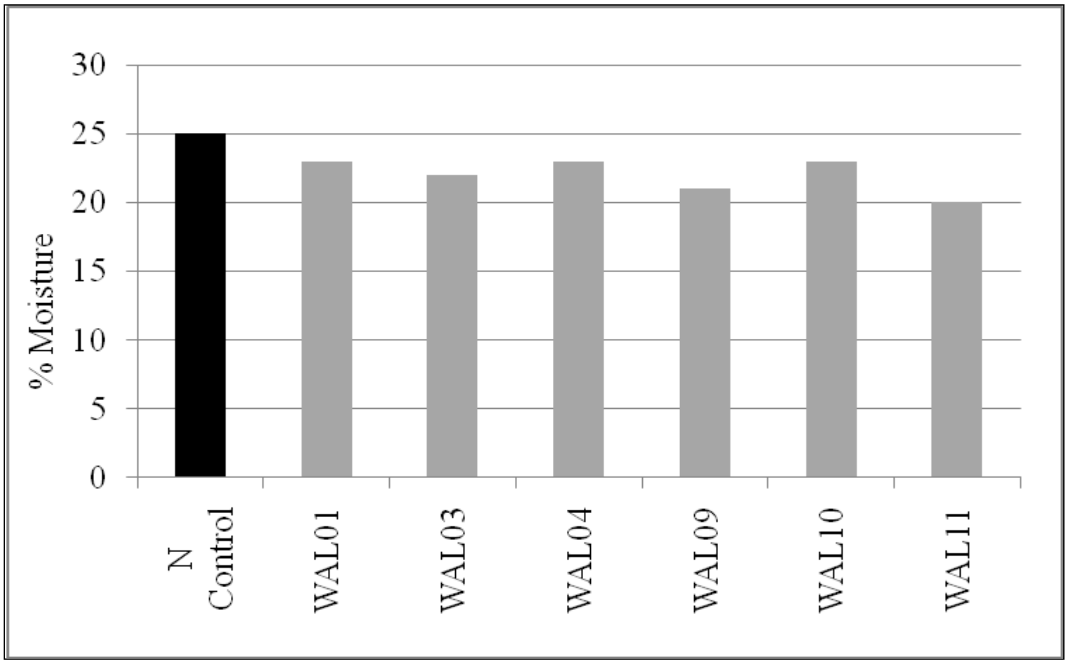

Figure 32. Average moisture percentage for North Waptus Lake campsites.

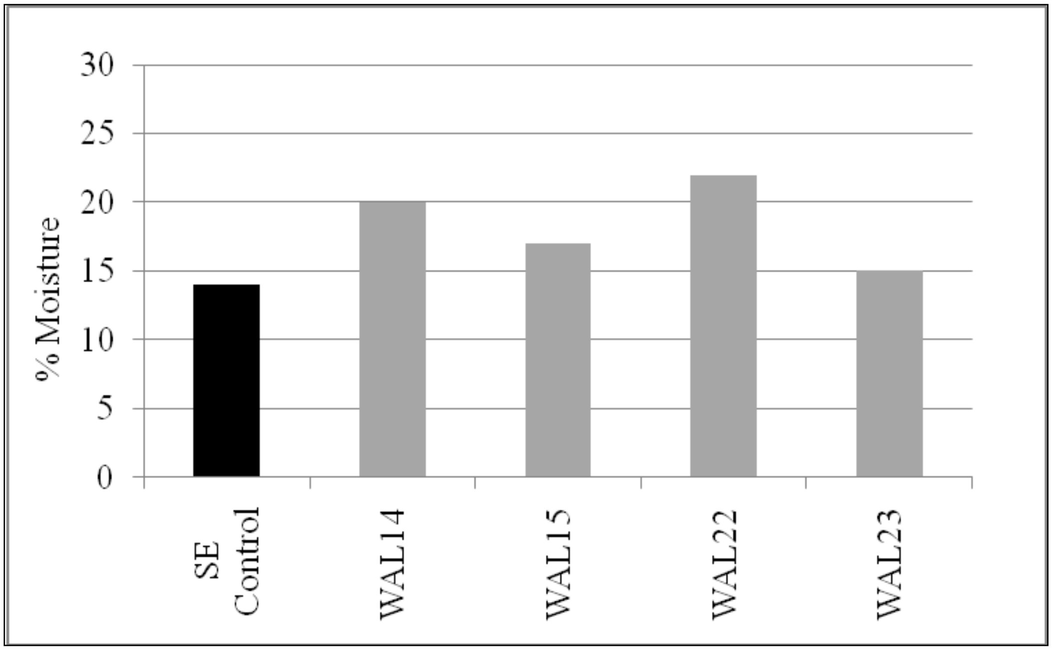

Figure 33. Average moisture percentage for Southeast Waptus Lake campsites.

Descriptive statistics for soil moisture (see Table 14) showed low variability between the North and Southeast campsite medians (0.2 in both cases) and slight variations compared to the control sites (0.2 & 0.1, respectively). Statistical comparison of North campsite soil moisture with Southeast campsite soil moisture found significant differences between the two sample areas (Mann-Whitney $U = 415.0$, $p < 0.001$, two-tailed test). The slight differences identified in the descriptive statistics may be due to microenvironment variability and percent of forest cover; however, the low variation of moisture suggests that recreational impact has had little effect on campsite soil moisture. The relationship between percent of soil moisture and campsite impact does not appear to be a significant (Kruskal-Wallis, $p = 0.40$).

Table 14

Descriptive Statistics for Waptus Lake Soil Moisture.

Soil moisture	North campsites	North control	Southeast campsite	Southeast control
Median	0.2	0.2	0.2	0.1
Maximum	0.3	0.3	0.3	0.2
Minimum	0.1	0.2	0.1	0.1
Interquartile range	0.2	0.1	0.2	0.0

Organic Matter Content

The organic loss on ignition (LOI) procedure resulted in a range of organic content from 4% to 45% weight by volume. The data averaged by site yielded results with a range from 5% to 21%. Averaging the data reduced the range, but continued to yield highly variable results (see Figures 34 & 35). There were no discernible patterns in regard to the location of high and low amounts of organic matter within each site or in comparison with the adjacent control sites. Further, the campsites with the highest levels of organic matter had very little in common with one another in regard to campsite

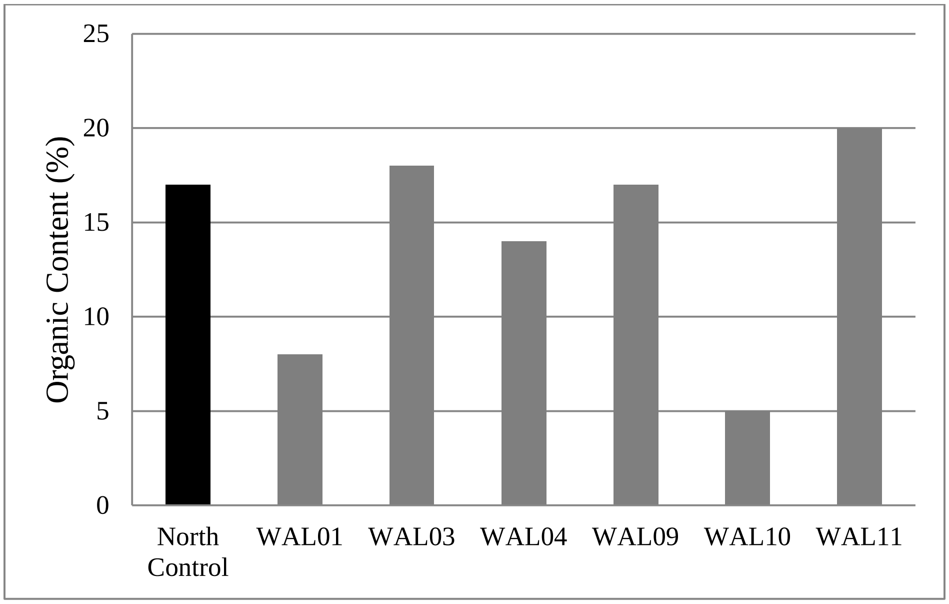

Figure 34. Average percent soil organic content for North Waptus Lake campsites.

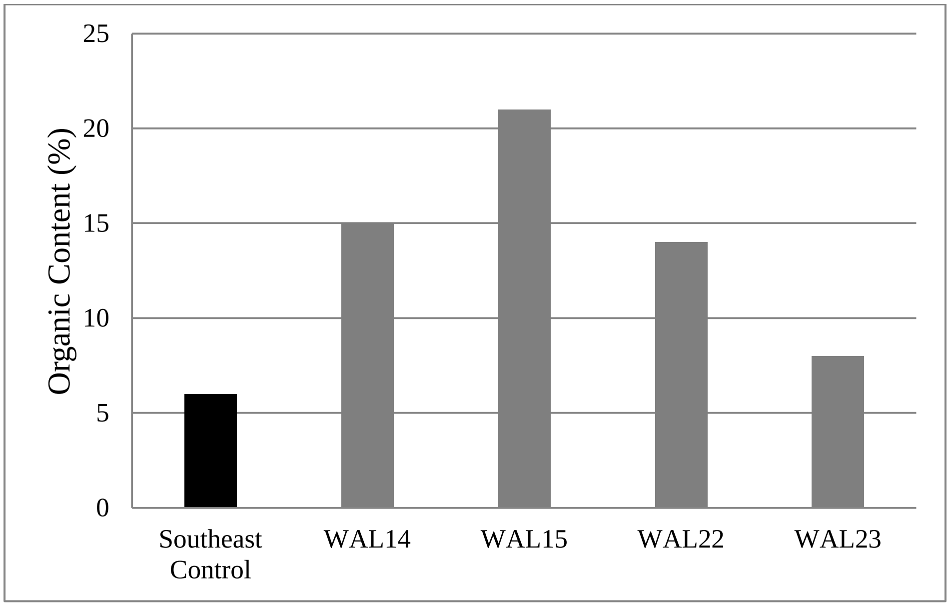

Figure 35. Average percent soil organic content for Southeast Waptus Lake campsites.

location or type of dominant vegetation. The soil textures in the campsites with the highest percent of organic content were loams and sandy loams. However, the campsites with the lowest percent of organic content were also loams and sandy loams (Table 18). Since the organic content in campsite soils varied considerably and compaction is directly related to the amount of organic matter in a soil (i.e., lower organic matter leads to increased long-term compaction as Greacen, 1980, concluded), there is likely a relationship between compaction and organics.

Statistical analysis of organic content compared to the BMREP results yielded a significant relationship (Kruskal Wallis, $p = 0.02$); however, when data were analyzed to determine if a association exists between organic content and soil moisture, results showed a weak positive correlation ($r_s = 0.136$, $p = 0.357$). Descriptive statistics show a low level of variability between the impacted campsites and the control sites (see Table 15), suggesting that soil organic matter should not have an influence on campsite impact recovery.

Table 15

Descriptive Statistics for Waptus Lake Soil Organic Content.

Soil organic content	North campsites	North control	Southeast campsite	Southeast control
Median	0.1	0.2	0.1	0.1
Maximum	0.5	0.2	0.3	0.1
Minimum	0.0	0.1	0.0	0.1
Interquartile range	0.4	0.1	0.2	0.0

These results indicate that Waptus Lake campsites are comprised of organic, moderately moist, loam soils (Brady & Weil, 2008; Hammitt & Cole, 1988). Each of these factors contributes to the susceptibility of soil compaction (Manning, 1979), suggesting that Waptus Soils are naturally prone to compaction due to moisture and texture; however, the abundance of organic content indicates the potential for successful restoration efforts attempting to revegetate damaged soils (Greacen, 1980).

Soil pH

Potential hydrogen (pH) results of Waptus Lake soils were particularly interesting, as nine out of ten averaged samples were different compared to the control sites. The differences in pH between impacted campsites and control sites were highly significant ($U = 282.5$, $p < 0.001$, two-tailed test). The results of pH measures at Waptus Lake range from an extremely acidic 3.9 to moderately acidic 5.8. Averaged pH data for the north shore campsites yielded a measure of 6.4, which was a substantial increase over the averaged control measure of 5.2. The southeast shore showed a similar pattern, with averaged pH on impacted campsites measuring 6.6, compared to the averaged control site pH data of 5.5. The majority of pH measures were between 4.5 and 5.0, or very strongly acidic (see Figures 36 & 37).

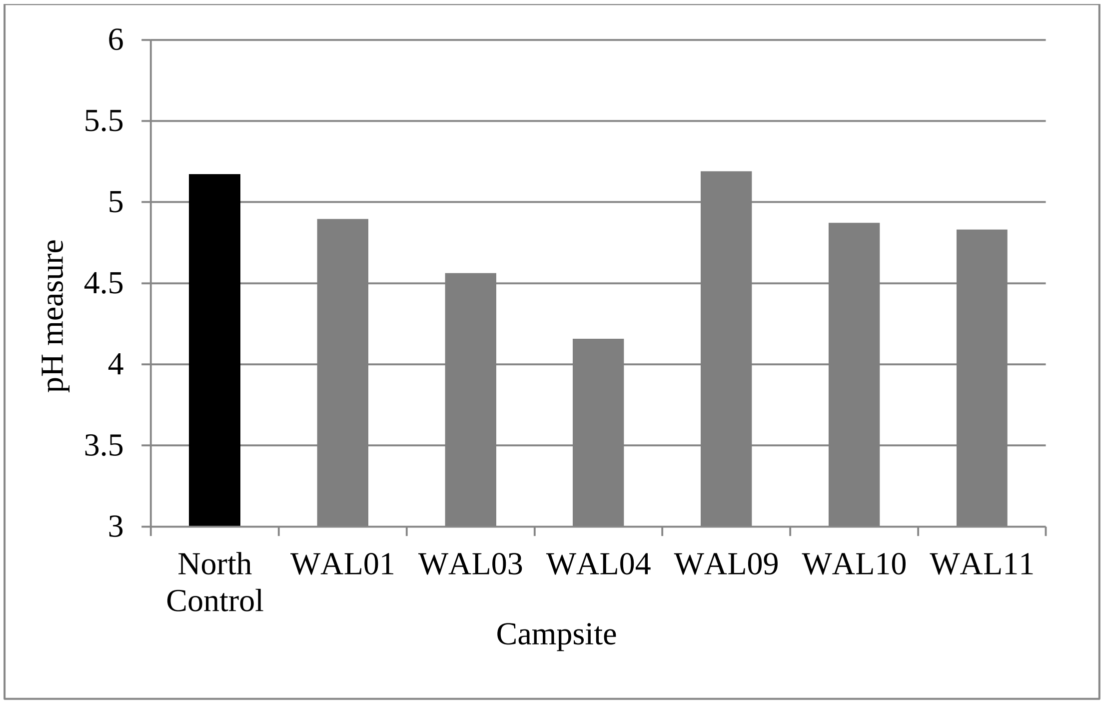

Figure 36. Average pH of north shore Waptus Lake soils.

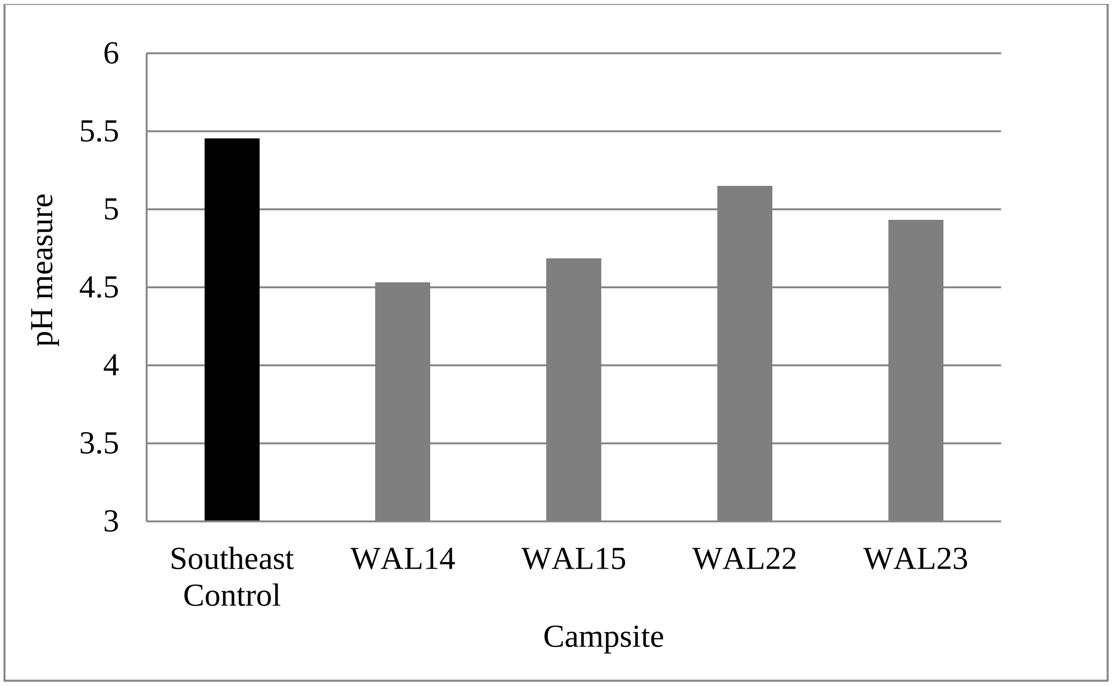

Figure 37. Average pH of southeast shore Waptus Lake soils.

A statistically significant relationship was found between campsite soil pH and BMREP impact ratings ($H = 60.447$, $p < 0.001$), suggesting that increasing campsite impact affects soil pH. A weak, negative correlation was found comparing the percent of soil moisture to campsite pH ($r_s = -0.203$, $p = 0.165$) and a weak positive association between percent organic content to campsite pH ($r_s = 0.166$, $p = 0.257$). Descriptive statistics further illustrate the variability of pH measures (see Table 16). The interquartile range for North shore and Southeast shore campsites are 2.1 and 2.7, respectively. This range is substantially different compared to the interquartile ranges of the north and southeast control sites (both 0.6).

Table 16

Descriptive Statistics for Waptus Lake Soil pH.

Soil pH	North campsites	North control	Southeast campsite	Southeast control
Median	6.7	5.3	7.0	5.4
Maximum	7.0	5.4	7.0	5.8
Minimum	5.0	4.8	4.4	5.3
Interquartile range	2.1	0.6	2.7	0.6

These results are interesting because most of the campsite pH measures were lower, or more acidic than the control sites. The north control site averaged 5.2, which is high compared to the typical 4.6 measure cited in the Vabus series description, and the southeast control averaged 5.5, which is low compared to the typical 6.4 measure cited in the Kladnick series description (NRCS, 2010). The literature in regard to campsite pH delivers conflicting results. Waptus Lake findings contradict published studies that found campsite pH to be higher on impacted campsites compared to control sites (Cole, 1987; Hammitt & Cole, 1998), but corroborates other studies that identified a decrease in pH (Alessa & Earnhart, 2000).

These strongly acidic soils may be experiencing a side-effect of compaction which is an accumulation of soluble aluminum or manganese which may be toxic to plants (Hausenbuiller, 1985; Kuss, 1986; Taylor, 1995; Alessa & Earnhart, 2000). Since the oxidation of organic material influences pH, it would be reasonable to consider that the depletion of vegetation on campsite soils has reduced organic content, thus increasing pH levels. These findings also corroborate the accumulation of soluble aluminum or manganese theory suggesting that compaction affects soil pH (Hausenbuiller, 1985; Kuss, 1986; Taylor, 1995; Alessa & Earnhart, 2000).

Reduced pH levels on Waptus Lake campsite soils may be of concern in regard to potential restoration projects. Changes in soil chemistry may impact the ability of native plants to process soil nutrients, and ultimately survive. Since pH measures were limited to the surface soil and we do not have data regarding the other soil horizons, it is difficult to predict the long-term effects of the increased acidity. It is possible to have a strongly acidic surface layer underlain by alkaline layers in the subsequent soil horizons (Foth & Ellis, 1988). If this is the case, the acidity of the surface horizon could have little or no effect upon the root zone.

Compaction

Compaction results, measured by averaged drop cone penetrometer data, indicated that four out of seven Waptus Lake campsites are more compacted compared to the soils outside the impacted area (see Figures 38, 39, 40, 41, 42, 43, & 44). Campsites WAL 01, WAL 04, and WAL 22 were not measured due to rocky conditions that would have damaged the measurement equipment. Statistical analysis of compaction by comparison of penetrometer depth outside of impacted campsites with penetrometer depth inside the campsites found the difference between the two samples to be significant (Wilcoxon Signed Rank $T = 0.283$, $p < 0.777$ two-tailed). Descriptive statistics also demonstrated this difference by comparing medians and interquartile ranges of impacted campsites and control site (see Table 17). Further, in five of the sites, the campsite core had the highest compaction (Cole & Monz, 2004). Due to differences in campsite size, the transect distance in relation to the control sites vary. Campsite WAL 10's (Figures 16 & 40) compaction profile is more dramatic than the others, likely due to the alluvial fan's dry, sandy conditions which allowed the drop cone to penetrate the soil to a greater depth compared to the other campsites. This was especially true for the first and last measures located outside the impacted zone.

Table 17. Descriptive Statistics for Waptus Lake Soil Compaction

Soil Compaction	Impacted Campsite	Control Sites
Median	6.8	5.32
Maximum	7.0	5.83
Minimum	4.35	4.79
Interquartile range	2.65	1.04

In addition to the pattern of compaction, the data also contained variable results, as indicated in campsites WAL 14 and WAL 15 (Figures 42 & 43) where compaction was less noticeable compared to the control measures. The reason for this is probably because the area is located further from the water and has been used as a packstock camp. Heavy packstock impacts have likely led to increased bulk density and compaction throughout this large area, which features level ground in an open forest, making the edge of the campsite difficult to identify. These findings are consistent with other packstock impact findings that suggest the intensity of weight and the area required for tethering packstock leads to a greater spatial extent and magnitude of impact (Hammitt & Cole, 1998; L. Therrall, personal communication, May 9, 2011).

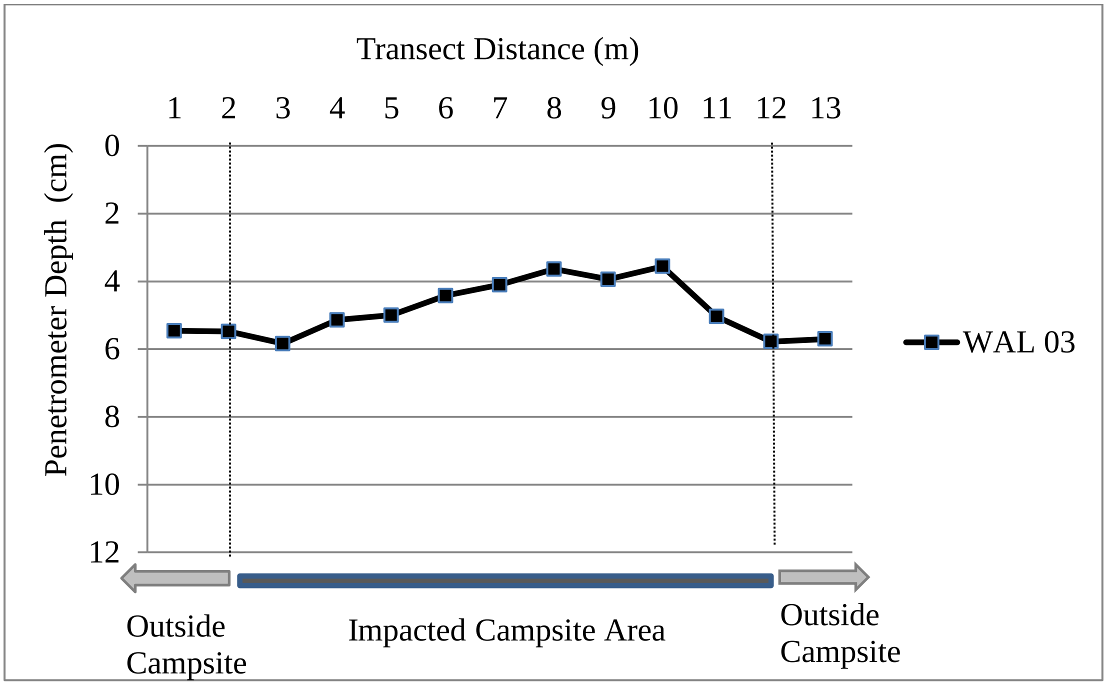

Figure 38. Compaction profile of campsite WAL 03. *Note*. The zero measure is located at the top of the vertical axis to indicate the soil surface.

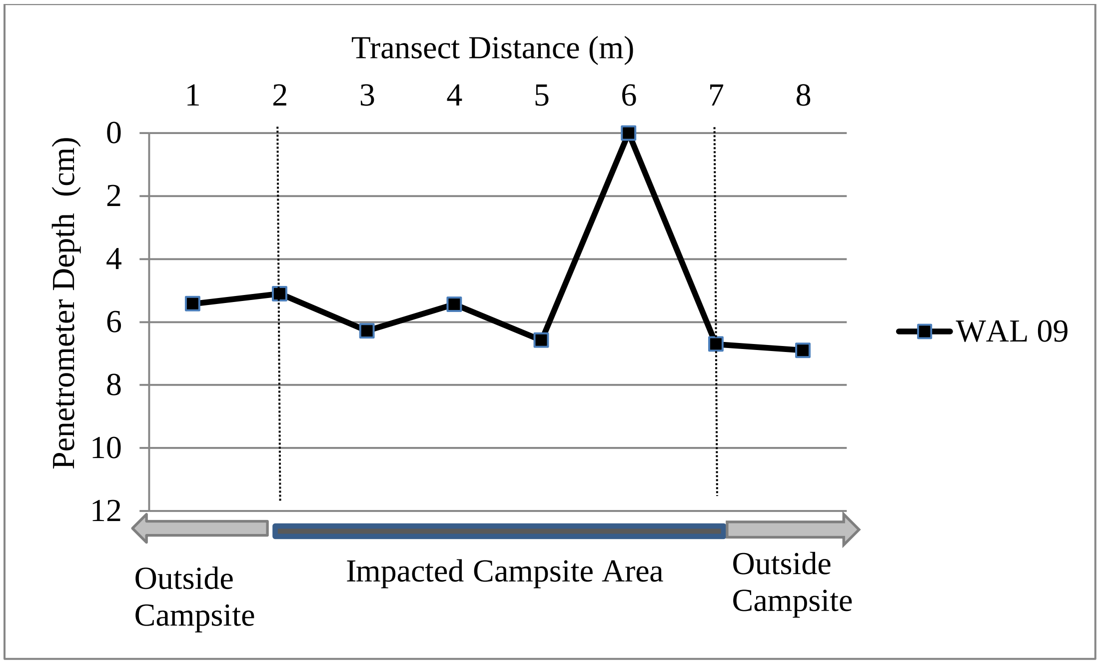

Figure 39. Compaction profile of campsite WAL 09. *Note*. Penetrometer readings recorded as 0 cm indicate no measure due to the presence of rocks at the location.

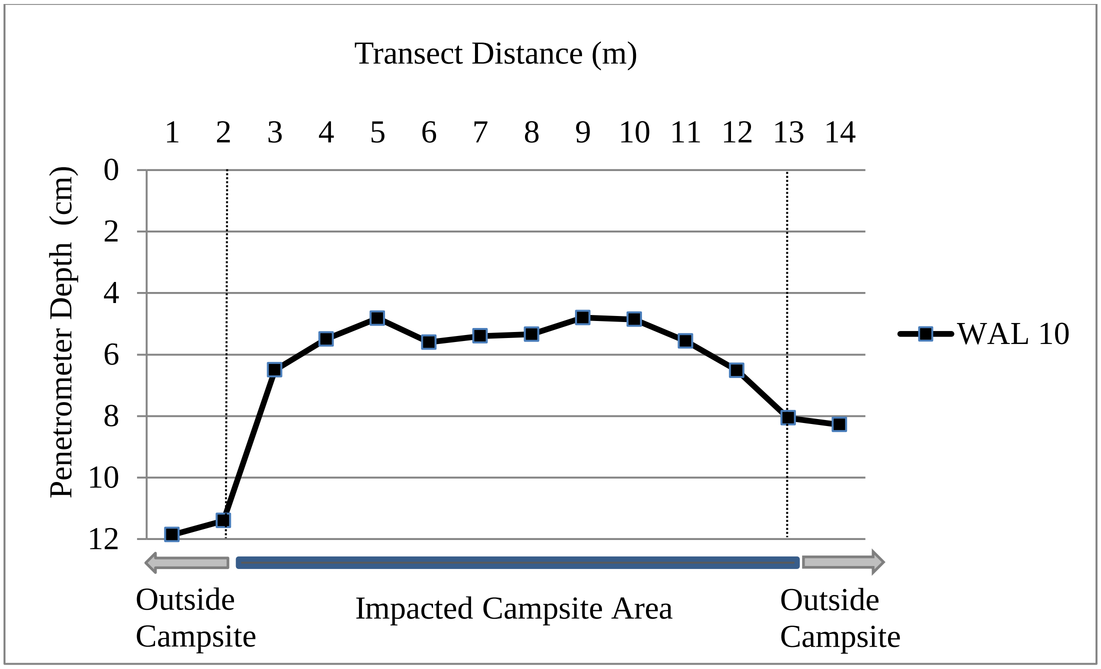

Figure 40. Compaction profile of campsite WAL 10.

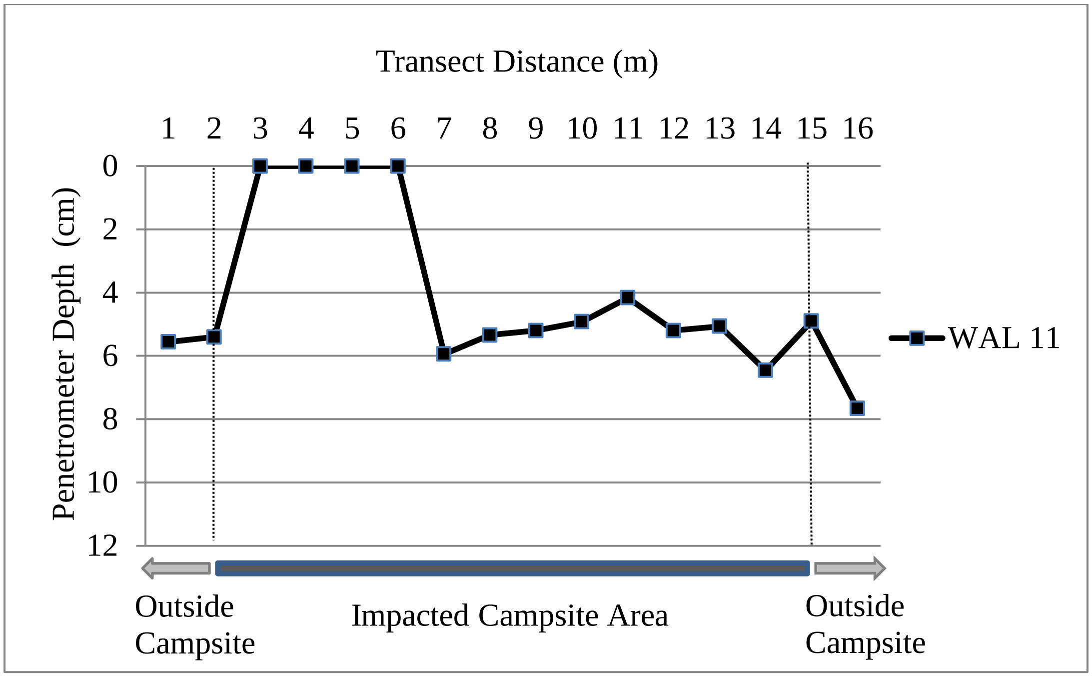

Figure 41. Compaction profile of campsite WAL 11. *Note*. Penetrometer readings recorded as 0 cm indicate no measure due to the presence of rocks at the location.

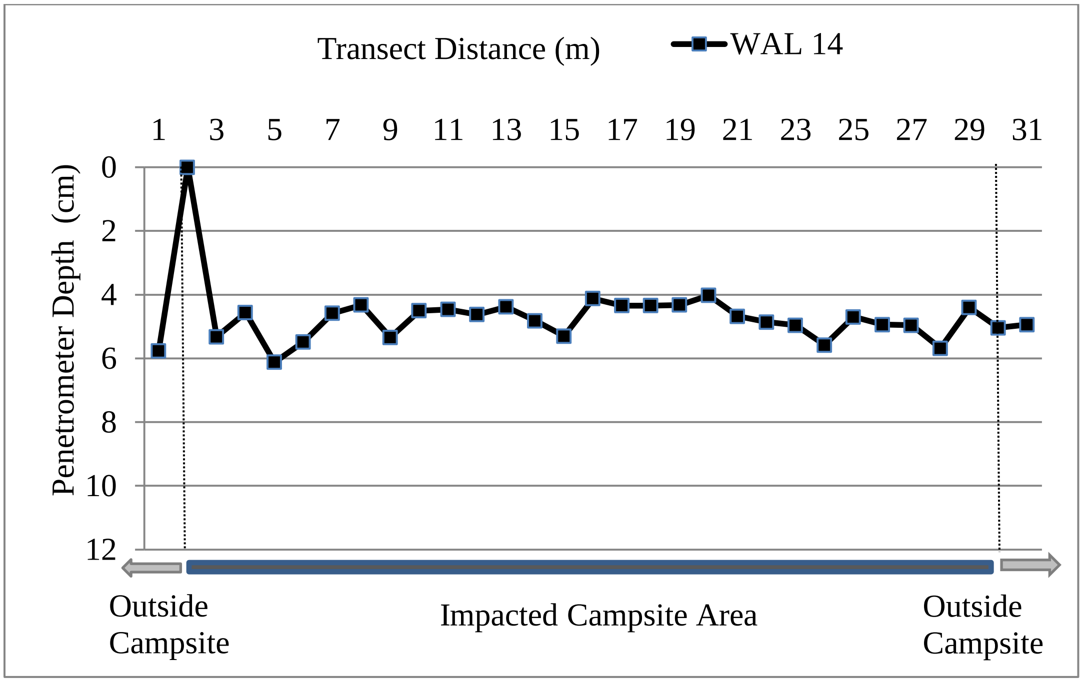

Figure 42. Compaction profile of campsite WAL 14. *Note*. Penetrometer readings recorded as 0 cm indicate no measure due to the presence of rocks at the location.

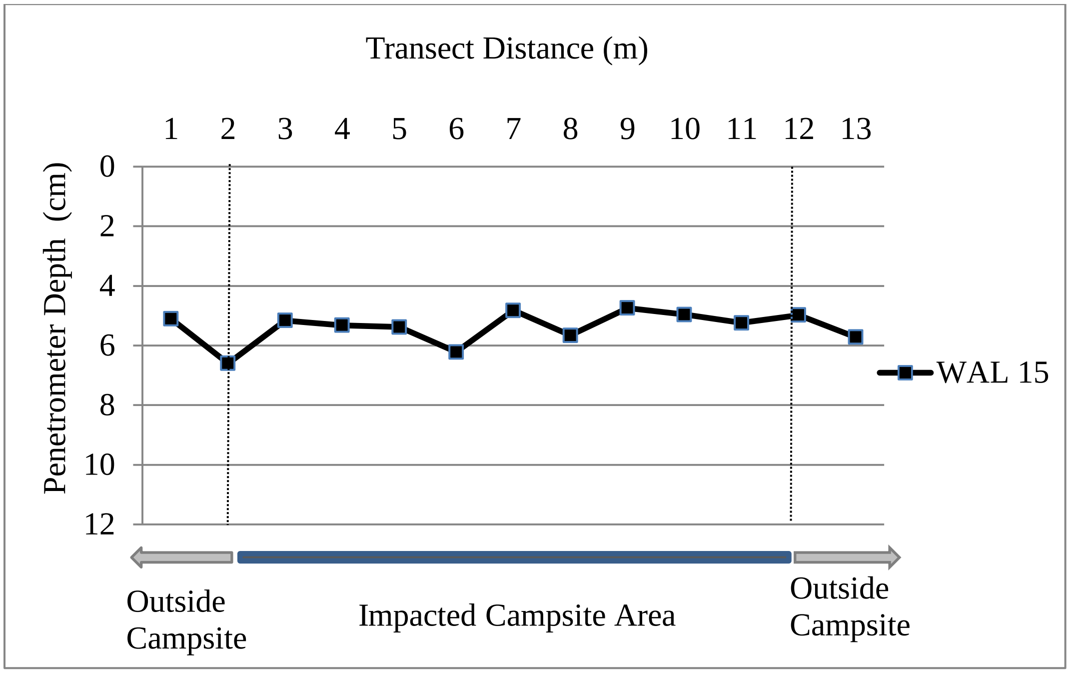

Figure 43. Compaction profile of campsite WAL 15.

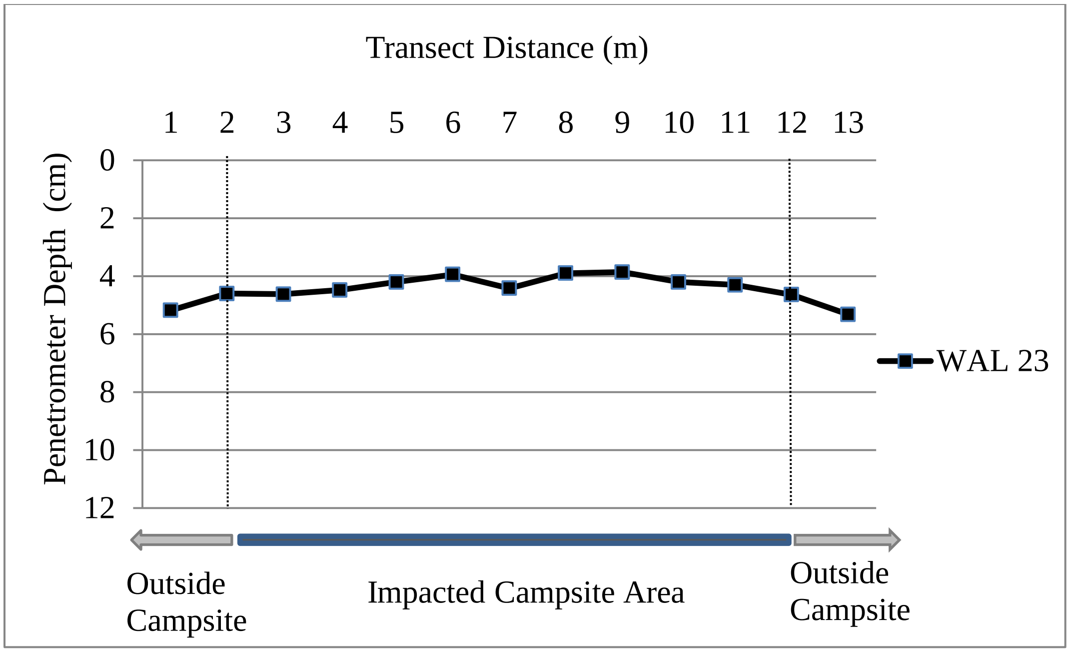

Figure 44. Compaction profile of campsite WAL 23.

Results indicate that recreational impacts and intensity of use have altered the soil texture, porosity, and percent moisture, leading to compacted campsite soils (Kuss, 1986). These data suggest that the parent material, climate, and intensity of use make Waptus Lake soils prone to compaction and increased bulk density. The compacted profiles confirm that the soils are experiencing negative impacts associated with trampling, including scuffing away of leaf litter, loss of organic material, reduction of soil macroporosity, reduced air and water permeability, reduced water infiltration, increased water runoff, and increased soil erosion (Figure 2; Belnap, 1998; Hammitt & Cole, 1988; Manning, 1979; Marion & Cole, 1996).

Waptus Lake Trailhead Data and Use Trends over Time

Analysis of trailhead use from 1996 to 2008 showed a decreasing trend of overall use of the Waptus River trailhead during this period (see Figure 45). The Spearman's Rank Correlation statistical analysis confirmed the decreasing trend in trailhead use, as there is a fairly strong negative or inverse correlation between year and trailhead use of the Waptus River trailhead for this time period ($r_s = -0.6088$, $p = 0.03$).

Figure 45 also demonstrates a less dramatic decrease in packstock and dog use, with the number of dogs closely mirroring the packstock trends. The theory that a significant relationship between the number of packstock per person and wilderness trip duration was corroborated by chi-square statistical analysis ($X^2 = 237.07$, $p < 0.001$) of the data set (see Table 18). The Cramer's coefficient ($V = .62$) indicates a fairly strong Chi-square statistic, meaning we can be confident in the results. These findings were also substantiated by agency personnel who are attempting to determine the appropriate

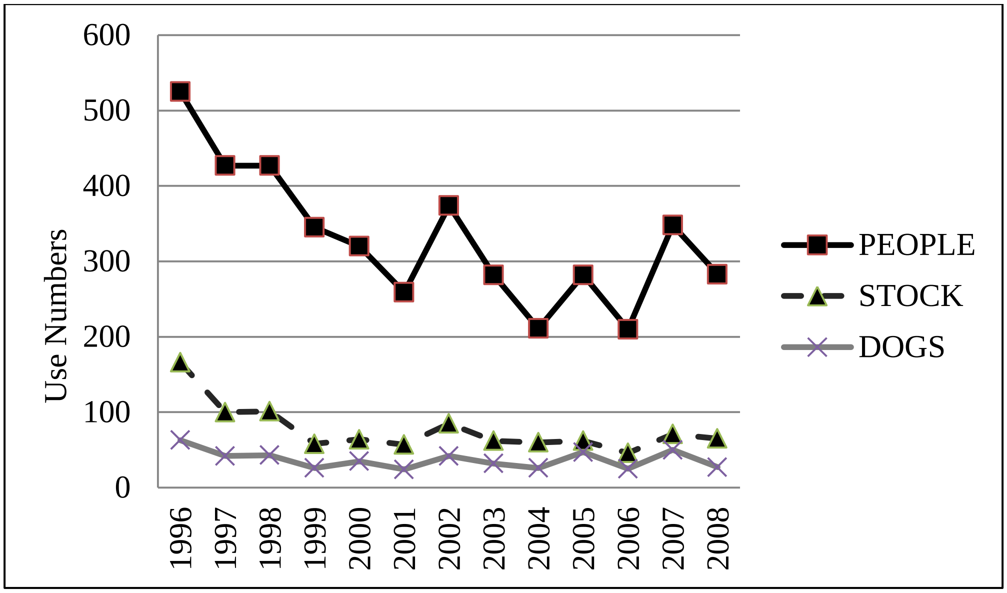

Figure 45. Waptus River Trailhead Use Trends from a 25 % sample of years 1996 – 2008.

Table 18.

Chi-Square Test Results for Samples with Packstock from 1996 – 2008

		Packstock Class			
People Class		1	2	3	
1	Observed	20.00	13.00	6.00	
	Expected	2.81	21.61	14.58	39
	Chi square	105.00	3.43	5.05	
2	Observed	1.00	152.00	47.00	
	Expected	14.43	110.82	74.75	200
	Chi square	12.50	15.30	10.30	
3	Observed	1.00	4.00	61.00	
	Expected	4.76	36.57	54.67	66
	Chi square	2.97	29.01	53.51	
		22	169	114	305

n	X^2	*p*	*df*
305	237.07	>0.001	4

campsite size for a packstock party consisting of the maximum group size. Initial estimates found that a packstock party including five people and seven horses, requires approximately twice the campsite size compared to a group of 12 people without horses (L. Therrell, personal communication, May 9, 2011). This decrease suggests that the 32 active site may be more than the number needed to accommodate use at Waptus Lake. It may be reasonable for land managers to identify a number of sites to close and restore, without needing to worry about displacing visitors for a lack of campsites.

In general, these use trends are contrary to national wilderness trends (Cole, 1996; Cordell, Betz & Green, 2008). Potential reasons for this decrease may be due to an overall decline in packstock use in the region, as Waptus Lake is a popular destination with that user group. The decline may indicate that wilderness users are favoring shorter, 5-8 km trips rather than the 14.5 km Waptus Lake route. It is important to note that these data are for the Waptus Lake Trail (1310) only; they do not capture the number of visitors accessing Waptus Lake via other trails (Figure 9), including the Quick Creek Trail (1329) via the Polallie Ridge Trail (1309), Trail Creek Trail (1322), and the PCNST (2000). Additional analysis would need to be completed in order to contemplate use trends for the entire ALW area. These data do, however, support the overall improved condition of campsites over the past 23 years. These results also support the theory that packstock leads to a greater spatial extent and magnitude of impact for multi-day trips compared to backpackers, due to the added impacts associated with tethering horses in or near the campsite.

The ALW permit data also provides basic detail about user characteristics, specifically the number of people and the duration of each trip. The Cle Elum Ranger District estimated the average trip duration to be two days and the average group size to be 3.5 (J.E. Morrow, personal communication, February, 2009). As illustrated in Figure 46, the estimate for duration was accurate; however, the estimate for group size was a little high. Actual group sizes from 1996 to 2008 averaged between 2.5 and 3 people.

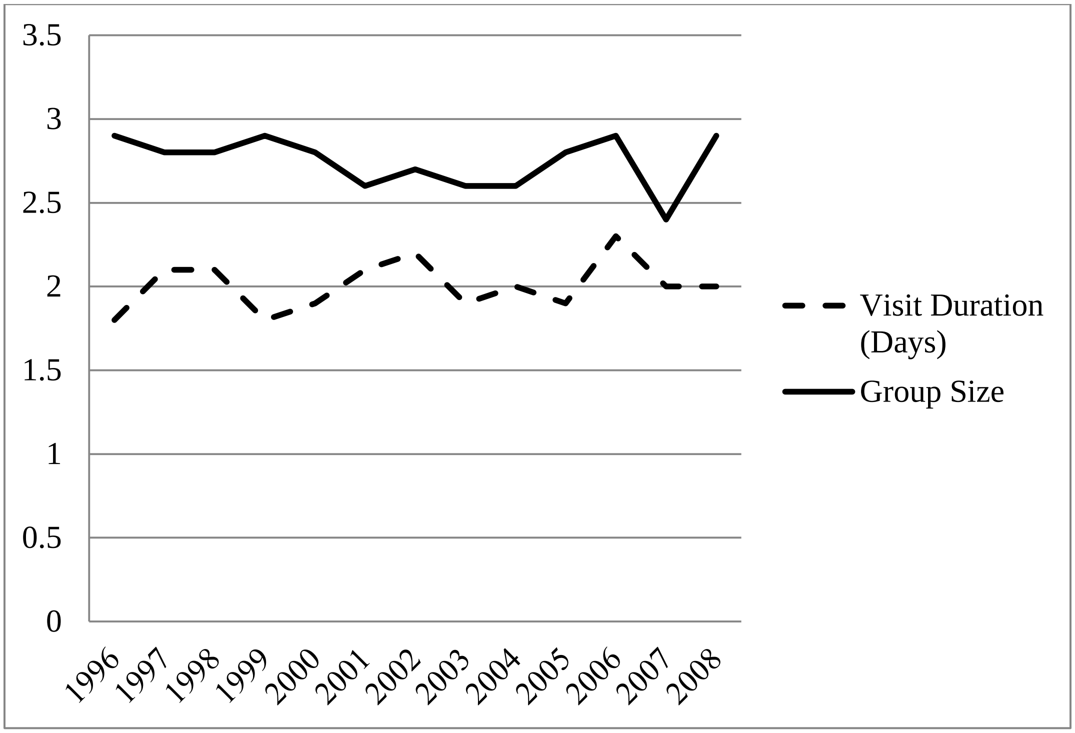

Figure 46. Waptus River Trailhead User Characteristics, 1996 – 2008.

The trip duration data are somewhat predictable for Waptus Lake. Due to the 14.5 km hike into the lake, it is an unlikely choice for a quick overnight stay. Visitors with time constraints are probably more likely to visit other lakes on the district with shorter access routes, like Pete Lake, and Hyas Lake, and the extremely popular Snow Lakes on the Snoqualmie Valley Ranger District. A district-wide wilderness trail data assessment would need to be completed in order to confirm this theory. The low average group size is encouraging for campsite impact recovery, as larger groups usually lead towards campsite sprawl and the development of social trails between campsites.

Analysis of the visitor estimation techniques revealed discrepancies between the two methods used to determine use numbers. A Wilcoxon Signed Rank test was conducted to evaluate if there was a difference between the weight estimate method and the hand count method. The results indicated a significant difference, $z = 10.5$, $p = 0.039$. Figure 47 compares the USFS weigh and estimate system with a hand-counted census. The difference between the two methods, indicated by linear trend lines on Figure 47, ranged from 1.5% to 27.3%, with an average of a 14.8% difference. These results indicate that the USFS was likely overestimating average annual use by approximately 15%. Results of the weigh and estimate method were missing for four years, so the sample size for comparison only includes 8 years of data. While the weigh and estimate method is not precise, it was surprisingly close in 1997. However, most other years were not accurate. This discrepancy may have had implications on the amount of staffing (i.e., Wilderness Ranger presence) and trail and volunteer work crews assigned to the area during this time period.

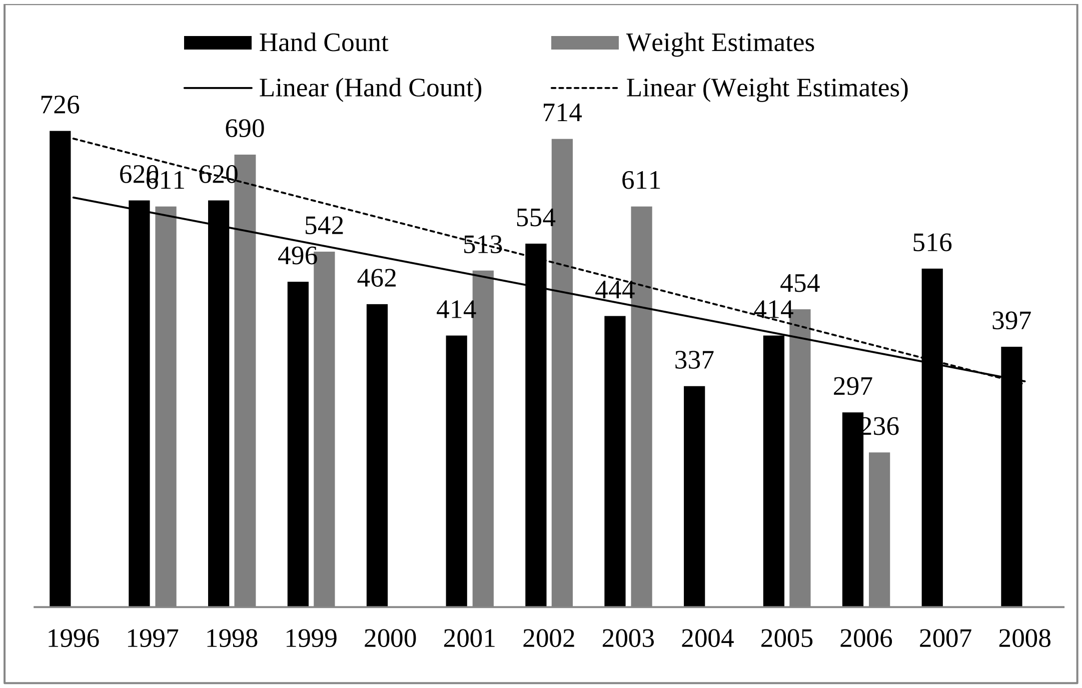

Figure 47. Comparison of the "weigh and estimate" method with the hand counted census results.

Management and Policy Recommendations for Waptus Lake

The congressional act of wilderness designation is a bold statement. It indicates that a specific place is distinctive enough that is deserves protection above and beyond National Park or National Forest status. Roads and mechanical devices halt at its border, yielding to resource protection, opportunities to recreate in solitude, and the advancement of scientific inquiry (Wilderness Act, Sections 2a & 4c). In the broadest sense, land managers have two options: they can chose adaptive management and work to actively restore resource conditions to the levels specified in area regulations, or they can water down the regulations to correspond with current impacts. The latter of which, arguably, condones mediocrity in these protected landscapes (Cole, 2007). The management recommendations outlined in this section are an attempt to achieve a compromise that is grounded in feasibility, while safeguarding the integrity of the wilderness landscape.

Spatial Extent of Campsites

Waptus Lake campsites are impacted to an extent that warrants an adaptive management approach and active restoration to reduce the spatial extent of campsite impacts (Table 7; Therrell et al., 2006). Field collected data from 2008 and 2009 revealed that only one (3%) of the active campsites at Waptus Lake complied with the 37.2 m^2 maximum size stated in the ALALMP (USFS, 1981). Individual campsite areas, on average were approximately 241.1 m^2, or six times the maximum square footage allowed in the ALALMP.

An interesting aspect about the discrepancy between the 1981 ALALMP campsite size criteria and current conditions is that 1985 data indicates that most of the campsites already existed when the plan was published (USFS, 1981). Based on this information, the Forest Service developed ALALMP standards that were considerably more stringent than the current on-the-ground conditions, and it lacked a narrative explanation regarding this problem and how they planned to address it. Wilderness managers representing the various ranger districts within the ALW are currently working on updating the management plan and will need to address this issue. Once completed, the new Okanogan-Wenatchee National Forest Land Management Plan (OWNFLMP) will replace the ALALMP.

Modify Campsite Size Regulation

One potential solution could involve changing the campsite spatial criteria listed in the ALALMP to be consistent with the LMP for the Okanogan-Wenatchee National Forest, which allows 92.9 m^2 for a wilderness campsite (Table 9; USFS, 1990). This option represents “the middle ground” in terms of restoration expense and personnel. In regard to campsite size, allowing 92.9 m^2 would change the percentage of campsites that are in compliance with the policy from 3% to 23%. Over 75% of the campsites would still require action to reduce their overall size, but that is more feasible than the current need to take size-related corrective action on 97% of the campsites.

In this scenario, I suggest that the Forest Service modify their current ALALMP to adopt the wilderness campsite size allotments outlined in the LMP (Table 9; USFS, 1990). The 92.9 m^2 limit has already been accepted by stakeholders, and is closer to a reasonable size to accommodate the maximum group size of twelve people in the ALW (USFS, 2010). If the USFS chooses to adopt this policy, it is important that they also clearly define how they identify the border of a campsite. It can be difficult to determine the exact border between the barren core and overall impacted area. This distinction is important for comparing baseline data with subsequent measures to determine if any adverse changes have occurred.

Utilize Large Woody Debris for Campsite Size Reduction

A distinct pattern emerged throughout the field research in regard to large woody debris. Many of the abandoned campsites were no longer used due to natural tree fall. As large diameter trees fall across the central area of a campsite, they render the area unusable. For example, campsite WAL 7 along the north shore (Figure 15) was a heavily impacted campsite in 1985 and 1988, but was difficult to locate in 2008. After several searches for the campsite in the general area indicated on the site map, we finally located an old fire ring under a large tree that had fallen through the middle of the campsite. I expect the same scenario explains WAL 8, which we failed to locate after several attempts. This pattern was also demonstrated in WAL 10 & 18 (Figures 15, 16, 19, 20, 21, & 22) where large woody debris fell adjacent to campsites, or through sections of established sites aiding in the reduction of overall campsite size as a natural campsite border. The presence of this material is also likely to create microclimates that stay moist, aiding in seed germination and survival (figure 21). A potentially economical and effective solution for reducing overall campsite size may simply be to yard in large diameter trees already down. These trees can be placed in a manner that delineates the desired campsite border and encourages microenvironment seedling establishment and eventual recovery of the excess area.

Address Areas with the Greatest Spatial Extent of Impact

The modification of campsite size regulations and utilization of large woody debris will help many campsites move towards acceptable conditions; however, the largest campsites will require active restoration (Table 8). Campsite WAL 17 adjacent to the lake is an example of an area that requires this attention. This site is located where the Waptus River Trail (1310) meets Waptus Lake (Figures 9 & 16), is the largest campsite (1,510.2 m^2) in the study area, and is only 9.2 m from Waptus Lake. The Waptus Lake Wilderness Report (USFS, 1988) recommended designating this site as day-use only due to the heavy impacts. I also recommend day-use only designation at this site. Further, I recommend this large area as a potential location to examine the soils response to treatments for campsite recovery (Table 8; Cole & Spildie, 2007). This approach would accomplish at least three goals: it would be an active approach to reducing campsite impacts and complying with ALALMP regulations, the research would provide useful information to guide future restoration efforts at Waptus Lake and beyond, and applying this approach at a popular focal point creates an opportunity to educate users about low impact camping techniques.

Allow Size Exceptions for Designated Large Group Campsites and Horse Camps

The 92.9 m^2 limit will remain a problem for larger groups and the packstock community, as evidence suggests that packstock groups require twice the campsite size of that required for non-packstock groups of the same number. For that reason, the USFS should consider designation of a few sites as large group campsites and allow a size exception to accommodate the space needed for multiple tents and for tethering animals (L. Therrell, personal communication, April 21, 2010). The topography of the southeast shore could easily accommodate these sites and they could be located near the areas that have functioned as temporary corrals since the 61 m setback was put into effect. The north shore could accommodate a large group campsite at WAL 31 (Figure 15) however, this site lies within 61 m of the lake. Otherwise, a large packstock camp set 61 m from the water will be difficult to accommodate due to the steep topography near the lake edge. A section of the North shore upslope from WAL 10 and 31 is currently being used for packstock; however, high erosion rates due to trampling and steep slopes make the southeast shore more suitable for this type of use.

If the USFS is going to enforce the campsite size restrictions and continue to support packstock use in the ALW, it will need to make adjustments for horse camps, consider temporary or semi-permanent packstock facilities, and think about seasonal restrictions. Provisional facilities such as high lines and temporary corrals erected by users for the duration of stay, or by the Forest Service on a seasonal basis may prove and effective tool for mitigating packstock impact. Use of signage could direct users to the temporary facilities in order to meet the goal of concentrating use into a defined area, while avoiding construction of permanent facilities. Stock-holding facilities are an effective last resort method for mitigating packstock damage; however, their compliance with the Wilderness Act is questionable. The Wilderness Act (Wilderness Act, Section 4c) specifically prohibits structures, although Forest Service policy permits them in order to protect resource conditions. Identifying one spot to serve as a packstock holding area would concentrate impact into a defined area, thus minimizing the spatial distribution of impact (Spildie, Cole, and Walker, 2000). Seasonal restrictions are a simple way of specifying the time of year packstock is permitted in the ALW with the goal of protecting soils early in the season when they are moist and most vulnerable to impact.

These strategies requires careful consideration as the proliferation of stock-holding facilities throughout wilderness areas is in conflict with the Wilderness Act, and the development of permanent facilities at a wilderness destination may create a draw for more packstock use. Once users are aware the facilities exist, they may change their use patterns to visit these destinations for the convenience of the facilities, which could lead to overcrowding. Consideration of these options is a timely matter, as the Washington State Horse Park recently opened in Cle Elum, with the goal of attracting tourism to the area within the packstock community, and eventually connecting the Horse Park lands into the adjacent National Forest backcountry (WSHP, 2011). Since Waptus Lake has historically been a popular packstock destination, this new facility may cause use levels to return to 1996 levels or higher (Figure 36). This situation may warrant the use of the MRDG to help analyze and justify the compromise between intentional manipulation and prohibited uses (Arthur Carhart National Wilderness Training Center, 2010).

Campsite Setbacks

Only five Waptus Lake campsites complied with the recommended 61 m setback from water and four active campsites complied with the recommended setback from trails (Table 14). The primary intent of trail setbacks is to protect the general wilderness experience, while the reasoning behind moving campsites away from water is based on protecting water quality (Leung & Marion, 2000). Research indicates that recreational impacts decrease water quality as a result of soil compaction, and ensuing increased runoff and erosion leading towards increased turbidity and nutrient input (Table 2; Leung & Marion, 2000). The Cle Elum Ranger District has chosen to not enforce the 61 m setback management direction since they have not found a practical method. Potential solutions to this discrepancy must be realistic in terms of on-the-ground implementation, meaning the USFS will need to have the wilderness personnel resources to implement and enforce the option, and it will need to be close enough to the intent of the Wilderness Act to be politically acceptable to conservation-minded ALW stakeholders.

Close and Restore Campsites Adjacent to Waptus Lake

An obvious option is to close all campsites within 61 m of Waptus Lake and create new campsites in locations acceptable to both trail and water setback issues. This would effectively eliminate all campsites along the North shore and concentrate sites to the Southeast area of Waptus Lake. The expenses associated with closing, restoring each campsite, and creating new campsites is prohibitive, however; partnering with groups like Washington Trails Association (WTA) and AmeriCorps could provide the initial labor force required to implement the campsite closures. Establishing a Mountain Stewards volunteer program could also provide labor and a longer-term presence to support the project's success and educate visitors about low impact camping techniques and why the changes have taken place.

A long-term project stewardship plan would need to be in place prior to project implementation as measurable site recovery may take years to achieve (Table 8; Cole & Spildie, 2007) and visitors used to camping next to the lake may resist the change. Engaging stakeholders with a Mountain Steward volunteer program would help create local support for the project. A volunteer-driven education campaign combined with enforcement may provide a model for success.

Address Water Quality Issues through Education

The alternative to this plan is removing the setback requirement in the ALALMP, and the development of a comprehensive educational campaign focusing on proper practices for camping near water (Zimmerman & Batura, 2006). Establishment of a Mountain Stewards program combined with this educational campaign can provide information through the USFS website, on signs at trailheads, printed on the required self-issued permits, and through public contacts through wilderness ranger patrols and the Mountain Steward volunteer presence. Along with this educational campaign, the USFS needs a strict policy that any new campsites created at Waptus Lake or anywhere else in the ALW area must comply with the 92.9 m^2 size maximum allowed for in the LMP and the 61 m setback requirement. If this alternative is followed, the general educational message should be to “concentrate impacts” by utilizing existing sites and staying within the existing footprint (L. Therrell, personal communication, May 9, 2011).

Designate Campsites

Campsite designation is another low-cost tool that would support the effectiveness of these recommendations. Stating that parties must camp within a designated site will discourage visitors from establishing new campsites. Small signs with images of tents or a combination of tents and horses can be posted. A few of these signs are already in place at Waptus Lake, mostly used to guide packstock users to sites that can accommodate horses. This option costs very little, and it gives wilderness rangers leverage to issue citations when groups of people cause adverse impacts by creating new campsites in previously undisturbed areas. If campsite designation is not feasible, an alternative would be to state in the Alpine Lakes regulations that users must camp on bare soil or other durable surfaces and avoid vegetation. Regulations are currently printed on the back of Alpine Lakes Use Permits, so it is likely that users would review the information. Both of these options would continue to require personnel in the field for education and enforcement.

Campsite Conditions

Many of the Waptus Lake campsites have shown an improvement in impact when compared to previous data (Table 14 & Figure 13). These improvements are likely attributed to declining annual use numbers, especially in regard to packstock, the requirement to tether packstock 61 m from water, and natural tree fall. Previous research has addressed the years required to achieve campsite recovery using various soil treatments (Table 8; Cole & Spildie, 2007). Due to the fine textured soil on the Southeast shore, recovery may indeed take years, however; coarse textured soil conditions along the North shore suggest that recovery can be achieved at a much faster pace (Brady & Weil, 2008; Cole & Spildie, 2007). Campsites WAL 7, 8, and 12 were abandoned sometime since 1988 (Figures 5 & 15). Campsites WAL 7 and 12 had recovered to a level that made them difficult to locate, and campsite 8 recovered to a point that it was not found at all. Based on this finding, efforts to remove and restore campsites adjacent to the North shore may recover at a different rate than the Southeast shore.

Visitor Management

The ALW group size allows for any combination of people and packstock equaling 12. As a comparison, the Spotted Bear Ranger District of the Bob Marshall Wilderness allows for 15 people and up to 35 packstock in one group (H. Castren, personal communication, February 11, 2009). The Selway Bitterroot and Frank Church Wilderness Areas allow up to 20 people and 20 packstock in a group and the Anaconda

Wilderness allows for 14 people and 14 packstock (M. Almquist, personal communication, February 11, 2009). The current ALW group size is restrictive compared to these other areas; however, the limitations are reasonable due to the area's popularity and proximity to major metropolitan areas. The group size of 12 is the regulation for the entire ALW as displayed on the self-issued permits located at trailheads. This number may be appropriate in a trailed setting; however, this group size in a pristine off-trail area would lead to significant adverse impacts. Due to the various conditions in different wilderness zones (Table 9), managers may need to consider further limiting group size based on wilderness zone (T. Therrell, personal communication, May 9, 2011).

Defining the carrying capacity for the specific wilderness zones will help land managers to consider the most appropriate group size (Cole & Carlson, 2010). This process may also lead to the development of criteria on which to base decisions about implementing a limited-use permit system. Forest Service policy states that: use should be limited if necessary to avoid impairment; any limits on visitor use should be based on estimates of visitor capacity; and capacity should be based on concerns regarding protection of both the biophysical resource and social conditions (Cole & Carlson, 2010). At a minimum, the process involved with identifying carrying capacity for different wilderness zones, including gathering information, monitoring, making decisions about thresholds, and prescribing management actions will contribute to effective impact management planning based on setting priorities and objectives to help achieve the desired resource condition.

CHAPTER VI

CONCLUSIONS AND FURTHER RESEARCH

Individual campsite areas were considerably larger than ALALMP regulations allow, with an average size of 241.1 m^2, or six times the 37.2 m^2 maximum. Most campsites were also found to be out of compliance with the management direction regarding setbacks from water and trails, with many located immediately adjacent to these attributes. These locational attributes affect the water quality of Waptus Lake (Leung & Marion, 2000) and the overall wilderness experience that the Wilderness Act seeks to create (Wilderness Act, Section 2a).

Waptus Lake, as a popular destination in the ALW, has experienced significant recreational impacts causing 100% of the campsites to be out of compliance with the ALALMP and management direction (Figures 18 & 19). The BMREP campsite impact assessments revealed a study site with 34% of the campsites rated as “severe”; however, overall campsite impacts improved significantly between 1985 and 2008 (Figures 21 & 22).

Assessment of biophysical conditions found that spodosol soils at Waptus Lake are naturally susceptible to compaction due to textural class and are experiencing the negative effect of trampling. Once a spodosols surface horizon has been destroyed, the soil type is very slow to support restoration (Buol, Southard, Graham & McDaniel, 2003). The fine textured inceptisols on the Southeast shore will likely respond to restoration efforts at a slower rate compared to the North shore and these soils will require intervention, such as scarification, addition of organics, and seeding (Table 7; Cole & Spildie, 2007).

A significant relationship was found between percent of moisture and percent of organic content; however, the low variation of moisture suggests that recreational impact has had little effect on campsite soil moisture, and soil organic matter. The acidic loam soils on the Southeast shore are of particular concern as they may limit the potential success of campsite restoration efforts.

Waptus River Trailhead data identified an inverse correlation between years and trailhead use demonstrating a decreasing trend of use at the Salmon La Sac trailhead from 1996 to 2008 (Figure 45). Further analysis of the data showed that while the Cle Elum Ranger District's estimate for average trip duration was accurate; their estimate for group size was approximately one person too high (Figure 40) and their weigh and estimate method of estimating annual use was overestimating annual visits by an average of 14.8% each year (Figure 47).

Additional packstock analysis demonstrated that a significant relationship exists between the number of packstock per person and wilderness trip duration. These results are important because they corroborate the theory that as packstock user trip duration increases; the ratio of people to animals also increases due to the need to transport additional gear for multi-day trips. These findings support the premise that packstock leads to a greater spatial distribution of impact for multi-day trips, due to the added impact of tethering horses in or near campsites.

Improved campsite conditions are likely due to the 1988 implementation of packstock setback policy allowing for shoreline vegetation recovery. Assuming that the Waptus Lake Trail is the primary access route, the decrease in overall visitors, and the decrease in visits from the packstock user group has also contributed to improved campsite conditions.

These findings have long-term planning implications for wilderness managers as they consider how to manage for the most sustainable recreation use in perpetuity. Wilderness regulations and management directions have little meaning if they are not enforced by the managing agency. Management can develop a stewardship plan to address current conditions, then implement, monitor, and evaluate the results for future wilderness applications, or they can reduce the ALALMP size regulations and management direction to fit the current campsite conditions.

Forest Service land managers need to face the difficult task of addressing their own compliance issues in a proactive manner, balancing implementation of management direction and feasible restoration methods. If specific regulations such as maximum campsite size are not achievable, those regulations need to be updated with new standards based on realistic use patterns and spatial impact research. It may be unreasonable to expect land managers to achieve the management direction regarding 61 m setbacks throughout the wilderness; however, it is reasonable to develop a list of priority areas where this action should be implemented. They also need to consider changes to the management direction that will curtail the expansion of recreational impacts by modifying the campsite size criteria and directing packstock use into areas already impacted in order to protect other, less impacted soils and vegetation, or using other campsite containment strategies like yarding in downed trees.

Visitor use data suggests that the 32 active campsites at Waptus Lake are in excess of the need. It is likely that many of these surplus campsites persist from the rampant use experienced between the 1960s and early 80s when families and groups maintained semi-permanent camps and group size limits we not in place.

Campsite impact monitoring, campsite spatial aspects, trailhead use, and campsite impacts are central resource management issues in most wilderness areas. When we fail to recognize negative trends associated with recreational use, the resulting impacts include excessive campsite size, compacted soils, loss of vegetation, increased runoff to streams and lakes, and damage resulting in denuded vegetation and trampling. The majority of research to date has focused on the impacts of hiking and camping on wilderness conditions. Relatively little attention has been paid to the specific impacts of packstock on the wilderness environment, mainly due to the fact that it is difficult to differentiate between packstock and non-packstock impacts from one campsite to another with reasonable certainty. The public’s perception of recreational and commercial packstock use on the character of wilderness can have significant policy ramifications as the suitability of this use in wilderness is called into question. In the last 10 years, there has been at least one major legal challenge against the Forest Service claiming that authorization of special-use permits to commercial packstock operators violates the National Environmental Policy Act, the Wilderness Act, the National Forest Management Act, and the Administrative Procedures Act (High Sierra Hikers Association v. Blackwell, 2003). The counterpoint made to this action is the “Right to

Ride" opinion purported by the Back County Horsemen of America claiming that use of packstock is a traditional and historic use in wilderness and federal agencies are unnecessarily and unfairly limiting equestrian access to public lands (BCHA, 2007). Based on this conflict, it is likely that additional legal challenges may arise questioning the compatibility of packstock impacts on the long-term sustainability of the National Wilderness Preservation System.

Wilderness managers are often asked to make a host of discretionary decisions in a very polarized atmosphere. When the management strategies are clear, these requests are easily dealt with; where the management direction is ambiguous or simply not feasible, the result is often controversy, confusion, and degradation of the resource elements. Once the USFS has a clear and feasible strategy in place, they can assemble a plan for getting their campsites into compliance. With the USFS enforcing their own management direction, users are more likely to respect the regulations and help protect the wilderness resource.

Further Research Opportunities

Additional Waptus Lake field research will complement the data represented in this analysis. Next steps at Waptus Lake include opportunities to further Juelson's (2001) campsite restoration research by comparing the effectiveness of different restoration treatments, i.e., placing large woody debris to encourage natural restoration, use of native vegetation plugs, and direct seeding for restoration purposes. These methods can be evaluated based on their application to areas with different soil texture, pH, levels of compaction, and soil moisture and organic content. The data collected in 1985 and 1988, combined with this research has primed Waptus Lake for a longer-term analysis on the best methods for addressing campsite impact and spatial issues at a popular mid-elevation lake on the Cle Elum Ranger District. A partnership between the Cle Elum Ranger District and the research community could yield positive results in regard to moving Waptus Lake campsites towards desired conditions while contributing to the campsite impact research body of knowledge.

As a response to the campsite management recommendations, there will be a need to close certain campsites and potentially establish new campsites. During this process, an opportunity exists to further Brunson's research on campsite selection criteria based on amenities (Table 1; Brunson, 1989).

Further opportunities exist for comparing packstock impacts with hiker only impacts. The differences between the two types of impact can be difficult to differentiate, however; Waptus Lake impacts could be compared to impacts found at ALW destinations where packstock is prohibited. One potential location is Spade Lake, located 6.8 km north of Waptus Lake. Another possible location is the Enchantment Lakes on the Wenatchee River Ranger District. The latter is unique because it has never been a packstock destination, while Spade Lake was closed to packstock in the late 1980s.

Results of this research may be useful in other mountainous, forested settings; however, its application to backcountry areas with different topography, soils and vegetation types may be limited. Similar studies researching campsite soils and impact patterns in areas dominated by forbs or shrubs would be useful in furthering the discipline of campsite restoration science.

Additional analyses of ALW user trends present another research opportunity. This study found overall use of the Waptus River trailhead to be decreasing, but that does not imply that overall wilderness use is on the decline. Since the average wilderness trip is only two days (Figure 40), users may choose shorter routes that are closer to the Seattle metropolitan area. The Waptus River trailhead is nearly two hours from Seattle and the hike is 14.5 km. Other popular ALW destinations are accessed nearer to Snoqualmie Pass, only an hour from Seattle with shorter approaches. Increasing trends of urbanization will only increase the literal and figurative value of wilderness areas. Further research on use trends would be useful in drawing detailed conclusions about recreation trends throughout the Alpine Lake Wilderness. National databases provide general numbers of wilderness visits as they relate to each National Forest, but they do not provide the detailed information needed to analyze local visitor trends. Understanding the relationship between complex use patterns and the biophysical resource condition is essential for maintaining this incredible natural resource.

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