Assessing Trail Degradation on the Hermit Trail, Glacier National Park, BC

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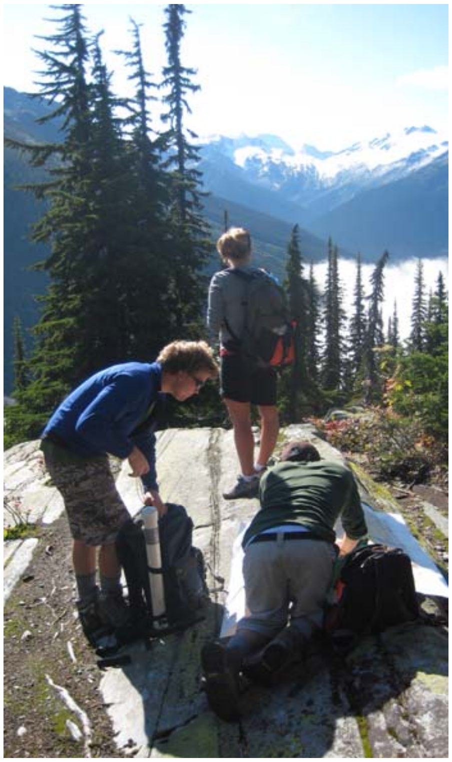
Abstract

The degradation of trial resources is a growing management problem in protected areas worldwide. Trails are an important component of the National Parks System as they provide access, offer recreational opportunities, and protect park resources by concentrating visitor use impact on tread surfaces. The type and extent of trail impacts are influenced by use-related and environmental factors. Management actions can modify such impacts. Fieldwork was conducted over two days in early September of 2008, to assess the condition of the Hermit Trail in Glacier National Park, BC. The primary objectives of the study were to assess the overall condition of the Hermit Trail, and use those assessments to make recommendations to better enable park managers to monitor and maintain the Hermit Trail. The condition of Hermit Trail was evaluated using systemic point-sampling and census-based approaches. Data was compiled using a condition-class system for ease of presentation and use. It was found that six of the sixteen points sampled were severely damaged, and that the overall condition of the Hermit Trail was moderately damaged. Soil erosion, root exposure, and the ineffectiveness of drainage ditches were the predominant impact factors that lead to these results. Management efforts should focus on the severely damaged sections of the trail in order to ensure ecological integrity is not compromised further. The information presented in this trail assessment report could be incorporated into future monitoring programs to identify trends in trail condition or to evaluate the effectiveness of management actions.



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1. <u>Introduction</u>

The degradation of trial resources is a growing management problem in protected areas worldwide. Trails are an important component of the National Parks System as they provide access, offer recreational opportunities, and protect park resources by concentrating visitor impact on tread surfaces. The deterioration of trails detracts from these major functions of National Parks. Trails are a recreation and tourism resource that requires both maintenance and protection (Marion, 2006).

Visitors have been an important part of Glacier National Parks since its establishment. While visitor use and enjoyment generates significant social and economic value, it can also degrade ecological integrity. As visitor numbers increase each year in the park, balancing preservation and use becomes ever more challenging.

The increasing dilemma of how to balance preservation and use values in Canadian protected areas has necessitated new research responses. The study of recreation ecology is a research response to the increasing pressure on wilderness areas from recreational visitors and examines, assesses and monitors visitor impacts (Hammit & Cole, 1998). The goal of recreation ecology is to understand and explore meaningful ways to mitigate impacts, preserve wilderness resources and provide meaningful recreation experiences. The term impact refers to any undesirable visitor-related biophysical change of wilderness (Leung & Marion, 2000).

According to numerous reports, visitor use is a primary “agent of change” affecting park vegetation, soil, wildlife and water resources (Leung &Marion, 2000; Hammit & Cole, 1998). Visitor traffic on trails can compact soils, widen the trail tread, exacerbate problems with muddiness, and accelerate soil erosion. Soil erosion has been found to be the most significant form of trail degradation. Ecologically, erosion is an irreversible form of impact, as soils that are transported off trial treads cannot be retrieved or replaced (Marion, 2006). Soil loss also exposes rocks and roots. These conditions have been found to affect the quality of recreational experiences and can result in difficult and unsafe travel conditions (Marion *et al*, 2006; Marion, 2006). A list of trail impacts and their ecological and social effects are listed in Table 1.

Figure 1. Trail impacts and their subsequent ecological and social impacts

Form of Impact	**Ecological Effects**	**Social Effects**
Soil Erosion	- Soil and nutrient loss, water turbidity/ sedimentation, alteration of water runoff, - Most permanent impact	- Increased travel difficulties, degraded aesthetics, safety - Increased restoration costs
Exposed Roots	- Root damage, reduced tree health, intolerance to drought	- Degrades aesthetics, safety
Wet Soil	- Prone to soil puddling, increased water runoff	- Increased travel difficulty, degrades aesthetics
Running Water	- Accelerated erosion rates	- Increased travel difficulty
Widening	- Vegetation loss, soil exposure	- Degraded aesthetics
Visitor-Created Trails/Secondary Trails	- Vegetation loss, wildlife habitat fragmentation	- Evidence of human, disturbance, degraded aesthetics

(Marion, 2006)

Trails are a fundamental component of most parks and wilderness visits. Trail impacts, according to park managers, are the most persuasive management problem and trail maintenance is a leading expenditure (Hammitt & Cole, 1998). Large sums of money are spent each year to maintain, rebuild, and relocate trails. These costs could be greatly reduced if we could predict where deterioration is likely to occur and how such deterioration could be minimized through trail location and design. Monitoring trial conditions will enable protective measures to be taken before more costly remedial actions are necessary (Marion, 2006).

The type and extent of trail impacts are influenced by use-related and environmental factors. Management actions can modify such impacts. This study has two primary objectives:

Objective 1: To assess the overall condition of the Hermit Trail.

Objective 2: To use assessments to make recommendations to better enable park managers to monitor and maintain the Hermit Trail.

It is hoped that the following report will help Glacier National Park preserve the ecological integrity of the Hermit Trail while providing outstanding opportunities for wilderness recreational experiences.

2. <u>Study Area</u>

Glacier National Park is a part of Canada's National Park System. It is located in Southeastern British Columbia in the Columbia Mountains (see Figure 1). It saddles both the Selkirk mountain range and the Purcell mountain range. The governing geomorphic processes are orogenic lifting, fluvial erosion and glacial action. Topography is controlled by the differences in resistance to erosion (Achuff *et al*, 1984).

The Selkirk Mountains are composed mostly of three bedrock groups: Hamil group, Lardeau group, and Shuswap metamorphic Complex. The Northwest Purcells are composed of Horsethief creek bedrock group (Achuff *et al*, 1984).

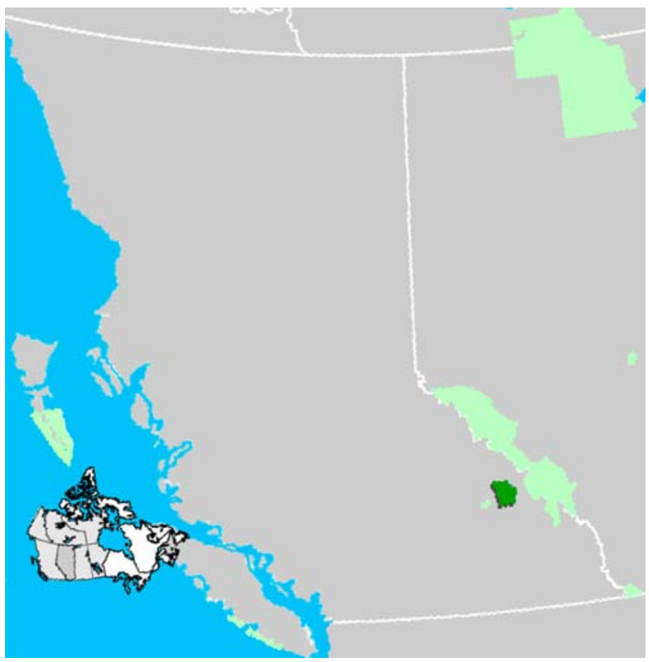

Figure 1. Location of Glacier National Park. Parks Canada

The climate of Glacier national park can be described as that of an interior rain forest. It has relatively mild winter temperatures, warm summer temperatures and an abundance of rain and snow throughout the year (Achuff *et al.*, 1984). Mean annual rainfall is about three times greater at the same elevation, in the Columbia Mountains when compared with the Rocky Mountains. The winter season has the highest level of precipitation due to mild and moist pacific air moving eastward. This makes up 65-70% of the total annual precipitation.

The study area for this project is the Hermit Trail located in Glacier National Park just off of the trans Canada highway1.5 km east of the Rogers Pass center. The high elevation access has made the area a popular destination for mountaineers since the Trans-continental railway was completed in 1886 (Parks Canada, 2008). The Hermit Trail is a steep climb with quick access to good climbing routes and scrambling (Parks Canada, 2008). The very nature of the trail makes it both highly used and gives it a relatively steep grade. The length of the trail is 3.8 km, mostly uphill with many switch-backs (See figure 2 for relative trail location).

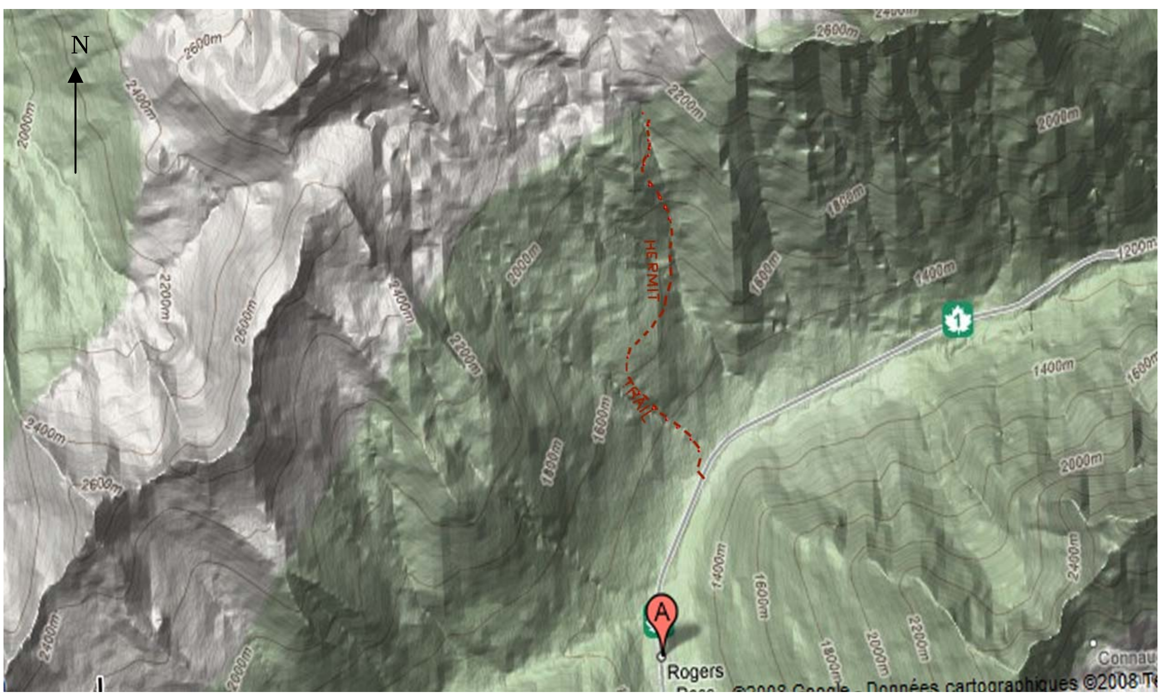

Figure 2. Hermit Trail, Glacier National Park, B.C.

The trail goes through three principle eco-regions: the Interior Cedar Hemlock (ICH) eco-region, the Engelmann Spruce-Subalpine Fir (ESSF) eco-region and Alpine eco-region. The location of these eco-regions is broadly determined by elevation.

Elevation dictates the air density, precipitation, and temperature amongst other factors, which can affect trail degradation processes. The ICH eco-region has a mean annual precipitation of 1000 to 1700 mm, with the maximum in winter and the minimum in April and late summer. Here snow and ice forms 35-70% of the total precipitation, increasing with elevation. The ICH eco-region occupies less than 2% of the park. The ESSF eco-region contains the subgroups of lower sub alpine fir and upper sub-alpine fir. ESSF is generally found above the ICH eco-region. Mean annual temperature is less than 1°C and decreases with increasing elevation. Precipitation is highest in this eco-region with a mean of 1700-2100 mm and the majority (60-80%) occurring as snow. The snow pack can last well into June or July. The alpine eco-region occurs above the two previously listed ecosystems. The alpine has the coldest most rigorous climate regime, which can be seen by the lack of forested vegetation and the shrub dominant ecosystem. The alpine may reverse the precipitation trend and it will decrease with increasing elevation. Strong winds can blow away much of the snow that accumulates in the alpine so an average snow depth gives an inconsistent measurement of snow. More than half of the park can be defined as this eco-region or as rock or glacier.

The high slope and high precipitation of the region means that fluvial action plays a very important part on trail erosion. The ease of access to the trail and panoramic views brought approximately 950 people to the Hermit Trail in 2008 according to Alice Weber of Parks Canada (2008). Visitor numbers peaked in July and August with 252 and 397 people doing the climb. Fortunately, visitor use is highest during the months when precipitation is at its minimum.

3. <u>Study Methods</u>

Fieldwork was conducted over two days in early September of 2008, on the Hermit Trail in Glacier National Park, BC. Two different trail assessment methodologies were employed to measure impact indicators along the sampled trail. The primary method used was a systematic sampling-based technique where tread assessments are evaluated at fixed intervals along the trail (Marion, Leung & Nepal, 2006, Leung & Marion, 1999). This method was found by Marion and Leung (2001), to provide more accurate and precise measurements of continuous (e.g. width or depth) or frequent trail characteristics. The first sample was taken at the top of the trail, in the alpine; with subsequent sample points established approximately every 250m. Distance between sample points was paced out by all four group members after determining an average number of steps for 250m (332 steps). This was done by using a tape measure on flat ground. UTM coordinates and elevations were recorded for each sample point, allowing for future replication and monitoring over time.

At each sample point, a transect was established perpendicular to the trail and a series of measurements were taken (Figure 3.). The bare ground width (area free of living vegetation) was measured using a tape measure. The maximum depth of the trail was measured by running a pole across the trail, with both ends resting at permanent ground height. The distance from the pole to the tread surface was measured at three equal intervals along the width of the tread using a tape measure. The middle measurement was recorded as maximum incision (MIC), a reflection of the maximum amount of soil loss within tread boundaries, thus an indicator of soil erosion (Marion, 2006). The vertical measurements were also used to calculate the cross-sectional area (CSA) between the tread surface and the pole, the most common method for measuring soil erosion (Cole, 1983). In addition, these values were extrapolated to provide an estimate of total soil loss (Marion, 2006). The CSA was calculated using the following formula:

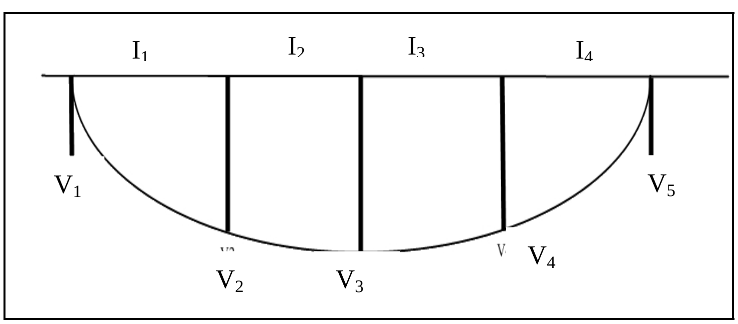

Figure 3. Technique for measuring MI and CSA.

$$Area^1 = (V1 + V2) \times Interval\ (I) \times .5$$

$$Area^t = A^1 + A^2 + A^3$$

Trail grade, or percent slope, was measured using a clinometer, placed on top of the pole, positioned in the middle of the tread, running parallel to the trail. An assessment of root exposure (tree or shrub) was conducted for a one-meter stretch of tread around each sample point. Four mutually exclusive, ordinal classes were used to describe the extent of root exposure (see Appendix 2, Figure 2 for visual examples of each class). The degree of compaction was measured at each site using a version of a penotrometer (see Figure 4.), a tool designed to measure penetration depth into soil, with increasing penetration depth suggesting decreased compaction. Three depth measurements were taken at each site using a digital caliper (0.01mm precision), one in the centre of the tread and one on either side of the tread ten inches from the trail boundary (the control). The difference in depth between the "out of trail" and "on trail" measurements were used to calculate trail compaction, as a percent, for each sample point. Soil samples from the first two to three inches of trail tread were also collected at each sample point. Soil properties can be an important indicator in determining erosion potential (Blanco, 2008). These samples were analyzed using a sieving analysis, the best-known and most common technique employed to measure particle size and sorting (Allen, 1997) (See Appendix 2 for sieving analysis methods).

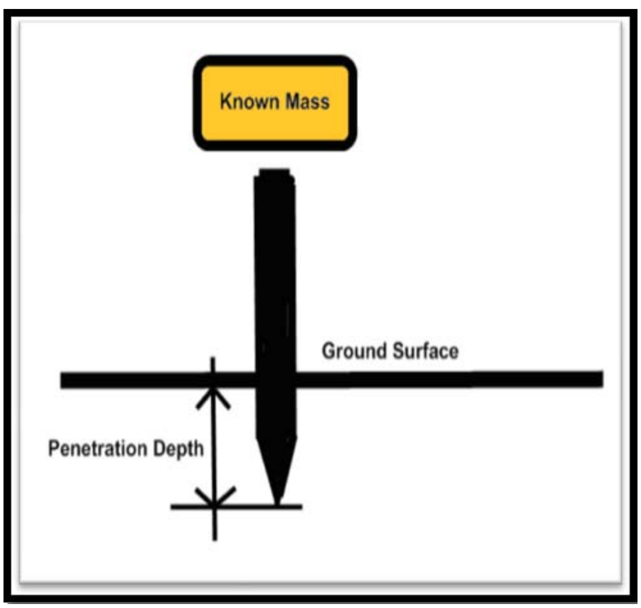

Figure 4. Penotrometer, consists of a stick with a pointed end (199.10 g) and a weight with a known mass (926.42 g), used to estimate percent compaction.

The second trail assessment methodology we employed was a census-based approach, whereby continuous assessments of the entire trail are made for a specific set of impacts (Marion *et al*, 2006; Leung & Marion, 1999). All drainage features (mostly water bars) found along the entire length of the trail were recorded, including an assessment of quality. Quality was based on estimated ease of drainage, relating to sediment build-up within these features, assuming that increased sediment will impede the flow of water. (Good = clear of detritus/free flowing, Medium = half filled with detritus/slightly impeded flow and Poor = completely filled with detritus/severely restricted flow). In addition to drainage features, general observations were recorded for each sample point (Appendix 1, Table 1.) and for the entire trail as a whole (Appendix 1, Table 2).

After data collection, averages for each trail condition indicator were calculated to aid in the assessment of the trail as a whole. In order to better present the results, values were broken up into classes based on previous literature when available. Otherwise class breaks were determined by the researchers best judgment.

4. Results

Results are presented below for two different types of indicators, inventory and impact (Marion, 2006). Inventory indicators are those variables that describe the physical attributes (trail grade, grain size and drainage features) of the trail (Table 2.). These are followed by impact indicators, which describe the condition of the trail (trail width, MIC, CSA, grain sorting and root exposure) and are used to assess overall trail condition (Table 3.).

4.1 Inventory Indicator Results

According to the universal soil loss equation (A=RKLSCP) there are 6 general variables that effects soil erosion:

- R: Soil erosivity factor, determined by total rainfall intensity and seasonal distribution of rain

- K: Soil erodibility factor, determined by soils inherent susceptibility to erosion, based on infiltration and structural stability
- L: Length
- S: Slope
- C: Cover & management factor: erosion and runoff affected by different types of vegetative cover and cropping systems
- P: Support practice factor, determined by physical structures or other steps aimed at guiding or slowing the flow of runoff water

The soil erodibility factor (K) and the slope (S) are examined in impact factors. Support practice factor (P) will be examined partially in inventory factors and discussed further in management. As length (L) was never measured and assumption of mean trail slope over mean trail length will not give an accurate representation, it will not be examined. Also the length between water bars was not measured so the length component is then irrelevant for the data gathered. The soil erosivity factor (R) will be discussed in management in terms of elevation and associated precipitation levels. Cover & management (C) will be examined in management and the discussion (Stone & Hilborn, 2000).

Trail grade ranged from 2 to 50% with a mean of 28.3%. The frequency distribution shown in Table 2 indicates that only one sample point (6.2%) is within the desirable range of grades (0-5%), established by the Parks Canada trail manual (1985). The majority of points (13 sample points, 81%) have grades in excess of 10%, generally considered to be high risk for soil erosion (Marion, 2006). Even more concerning is that 68.8% of the points have grades greater than 21%.

A total of one hundred and twenty-nine drainage features were observed along the trail, averaging one drainage feature every 30 m (Table 2). The condition of each drainage feature (considered an impact indicator but listed here) was also assessed based on three qualitative classes ranging from good to poor (definitions of each class can be found under methods). Forty-three sample points (33.3%) were in good condition, twenty-eight (21.7%) were in medium condition and the largest proportion (45%) were in poor condition. This provides an indication of the effectiveness of these features, in addition to, the quality and quantity of maintenance activities (Marion, 2006). This data can only be used to assess the overall trail condition, as it is not specific to each sample point. The drainage ditches are also a measurement of mitigation efforts used in the park. It should be noted that there were other erosion mitigation techniques present that we were not aware of at the time of our study.

Grain size ranged from Fine Silty Sand to Pebble (Table 2). One sample point is classified as pebble (6.5%), three points are Very Coarse Sand (20%), the majority of points (50.0%) fall under Coarse Sand, one point is Medium Sand (6.5%) and two points are Fine Silty Sand (13.5%). Soil erodibility is an estimate of the ability of soils to resist erosion, based on the physical characteristics of each soil (Wall & Baldwin, 1987). Generally, soils with faster infiltration rates and higher levels of organic matter have a greater resistance to erosion (Wall et al, 1987). Sand and sandy loam textured soils tend to be less erodible than very fine sand, and certain clay textured soils (Wall et al, 1987). Stations with coarse average grain size are thus considered to be at a lower risk for soil erosion. It should be noted that soils high in sands, such as the majority of soils in GNP, lack a high degree of plasticity. That is the degree to which they recover from a stress after the stressor has been removed (Curran et al, 2007)

Table 2. Number and percent of sample points by inventroty indicator category

Inventory Indicator	Sample Points	Percent
Grade (%)		
0-5%	1	6.2
6-10%	2	12.5
11-20%	2	12.5
>21%	11	68.8
Mean	28.30%	
Drainage Ditches		
Good	43	33.3
Medium	28	21.7
Poor	58	45.0
Total	129	
Grain Size*		
Pebble	1	7.1
Very Coarse Sand	3	31.4
Coarse Sand	7	50.0
Medium Sand	1	7.1
Fine Silty Sand	2	14.3

* Only 14 samples had measured values, two sample points (2 & 3) were located on stone steps so soil properties could not be measured

4.2 Impact Indicators Results

Trail width ranged from 0.50 to 1.90 m with a mean of 1.00 m (Table 3). None of the sample points had the recommended trail width (up to 0.45 m) established by the Parks Canada trail manual (1985). The majority of sample points (63%), however, fall within the maximum desirable limit (0.9 m) outlined in the manual. Only two points (12.5%) were greater then1.5 m, considered highly damaged by Marion *et al.* (2006).

Two measurements of erosion were used in this study, Maximum Incision (MI) and Cross Sectional Area (CSA). MI, or depth of the trail, was measured at each sample point with higher values indicating a higher degree of erosion. Incision values ranged from 3 to 24 cm with a mean of 12.8 cm (Table 3). Four sample points (28.6%) had incision values less than 10 cm and the majority of points (9 sample points, 64%) had incision values <15 cm, considered lightly damaged by Marion, Leung and Nepal (2006). Only 2 sample points had an incision value >20 cm (24 cm for both sample points), considered moderately damaged by Marion et al (2006), however, these values are just below what is considered significantly incised (25 cm) by Cole (1983).

The cross sectional area (CSA), considered a more accurate gauge of trail erosion, was also measured and calculated (Marion, 2006). CSA ranged from 81.3 to 2365.2 cm^2 with a mean of 845.6 (Table 3). Four sample points (28.6%) had a CSA <500 cm^2; 5 points (35.7%) exceeded 1000 cm^2 and only 1 point (7.1%) exceeded 1500 cm^2 but had an area of almost 1000 cm^2 more than the next lowest value (1431.0 cm^2). CSA values were extrapolated to estimate total soil loss for the entire Hermit trail. This estimate is based on the assumption that each sample point represents a trail distance of 125 m on either side, with the first and last point only representing 125 m total. Total soil loss was estimated at 2,668,487.5 cm^3, or 2.67m^3.

Root exposure was measured at each site using four qualitative classes ranging from minor to extreme (Table 3). Four sample points (30.8%) had minor exposure; half of the points (50%) had moderate to extensive exposure and only one point (7.6%) had extreme exposure. The category labeled extensive represents fairly severe root exposure and therefore, should be taken into consideration for remediation. There were five points (38.5%) that have extensive or extreme root exposure.

Compaction ranged from 0% to 74% with a mean of 46.8%. There was one negative value recorded at sample point one (-9.5%) (Table 3). This can be explained by a greater compaction outside the trail then within. The higher the percentage, the more the trail is compacted compared to the surrounding environment. Five sample points (35.7%) had a moderate compaction (31% - 60%) and half of the sample points (50%) had a soil extreme compaction (>60%). The erosion of soil by water is controlled by the following factors: rainfall intensity, runoff, soil erodibility, slope gradient and length of trail with our effective management (Wall *et al*, 1987). Compaction, in part, determines the soil erodibility factor (K). High compaction results in a decreased pore size and thus increasing bulk density. This allows for decreased hydraulic conductivity and increased runoff. Runoff can occur when there is excess water on a slope that cannot be absorbed into the soil or trapped on the surface. The amount of runoff can increase if infiltration is reduced due to soil compaction (Wall *et al*, 2003). Well compacted soils are considered to be at high risk for soil erosion as a result of runoff.

Sorting ranged from moderately to well sorted (Table 3). The majority of sample points (71.4%) are moderately sorted with four points (28.6%) recorded as well sorted. Sample points five, nine and eleven are the most poorly sorted.

Figure 5. Example of a severely incised portion of the trail

Figure 6. Example of a wide portion of the trail with fairly severe root exposure

Table 3. Number and percent of sample points by impact indicator category

Impact Indicator	Sample Points	Percent
Tread Width (m)		
0-0.45	0	0.0
0.46-0.9	10	63.0
1.0-1.5	4	25.0
>1.5	2	12.5
Mean	1.00 m	
Maximum Incision (cm)*		
0-10	4	28.6
11-15	5	35.7
15-20	3	21.4
>20	2	14.3
Mean	12.8 cm	
Cross Sectional Area (cm2)*		
0-500	4	28.6
501-1000	5	35.7
1001-1500	4	28.6
>1500	1	7.1
Mean	845.6 cm3	
Root Exposure**		
Minor	4	30.8
Moderate	4	30.8
Extensive	4	30.8
Extreme	1	7.6
Soil Compaction*		
0-30%	2	14.3
31-60%	5	35.7
>60%	7	50.0
Mean	46.8%	
Sorting*		
Poor	0	0.0
Moderate	10	71.4
Well	4	28.6

* Only 14 sample points had measured values

** Only 13 sample points had measured values

5. Condition Class Assessment

5.1 Methods

In order to assess trail condition at each sample point and assist in determining the overall state of the trail, a model was generated using reclassified impact indicators to create condition classes (see Appendix 2). Condition class systems are commonly used in visitor impact monitoring (Marion *et al*., 2006; Garland, 1990). A principal advantage of this method is its ease of application and simplicity in presenting the findings (Marion, 2006). All impact indicators were reclassified with values ranging from 1 to 3 (Appendix 2, Figure 2 & Table 1). Reclassified values were then added up and averaged for each sample point. It is important to note that some sample points did not have measurements for all indicators. These points were located in the Alpine, where a recently installed rock boardwalk prevented measurements of root exposure, compaction, MI, CSA and sorting. For these points averages were based on the number of indicators used. The final model assigned values ranging from 1 to 2.5 to each sample point (Appendix 2, Table 2). In order to create three mutually exclusive, qualitative condition classes all values less than1.5 were rounded down to 1 and all other values were rounded up. In addition, if sample points received a value of 3 for MI, CSA or root exposure, the sample point was automatically designated as severely degraded. The final three condition classes ranged from 1 to 3 with: 1 = lightly damaged, 2 = moderately damaged and 3 = severely damaged (Appendix 2, Table 2). A detailed description of each condition class is outlined in Table 4. To determine a rating for the overall condition of the trail the final condition class values (ranging from1 to 3) were added together and averaged.

Table 4. Detailed Description of the each condition class

Condition Class	Description
Class 1	Lightly Damaged: Either one or a combination of impact features are found. Trail can be considered stable and does not require any maintenance. - Compaction < 30% - Max Incision < 12 cm - Tread Width < 0.90 m - Cross-sectional Area < 1000 cm^2 - Minor Root Exposure
Class 2	Moderately Damaged: Trail condition appears to be deteriorating. Generally involves a combination of impacts but may be only one with major damage. Requires some degree of management. - Compaction 31-60% - Max Incision 12.1-20 cm - Tread Width 0.90-1.5 m - Cross-sectional Area 1000-1500 cm^2 - Moderate Root Exposure
Class 3	Severely Damaged: A combination of impacts or just one (MI, CSA or root exposure). Requires immediate repair/mitigation to avoid further deterioration. - Compaction > 60% - Max Incision > 20 cm - Tread Width > 1.5 m - Cross-sectional Area > 1500 cm^2 - Extensive/Extreme Root Exposure

Adapted from Marion *et al.*, 2006

5.2 Results and Discussion

Our final model categorizes six of the sixteen sample points (37.5%) as severely damaged, five points (31.24%) as moderately damaged and six points (37.5%) as lightly damaged (Figure 7). Points nine, thirteen, fifteen and sixteen were considered severely damaged due to a root exposure value of three (extensive/extreme). Point five was also categorized as severely damaged due to extreme root exposure and CSA and point six had an extreme MI. By averaging the results from the final model the overall trail was given a value 2 and was categorized as moderately damaged.

The results from this trail condition class assessment can be used to guide managers to those areas of the trail that are severely degraded and in the most need of maintenance. Our results show that sample point five should be considered first priority for maintenance activities due to a combination of severe impact indicators (MI, root exposure and trail width). Further efforts should be directed to all other all other points that were classified as severely degraded. By prioritizing areas of the trail in terms of maintenance needs, managers can focus resources on those areas most in need preventing further damage and potential costs. This is especially important when small budgets are allocated to maintenance activities.

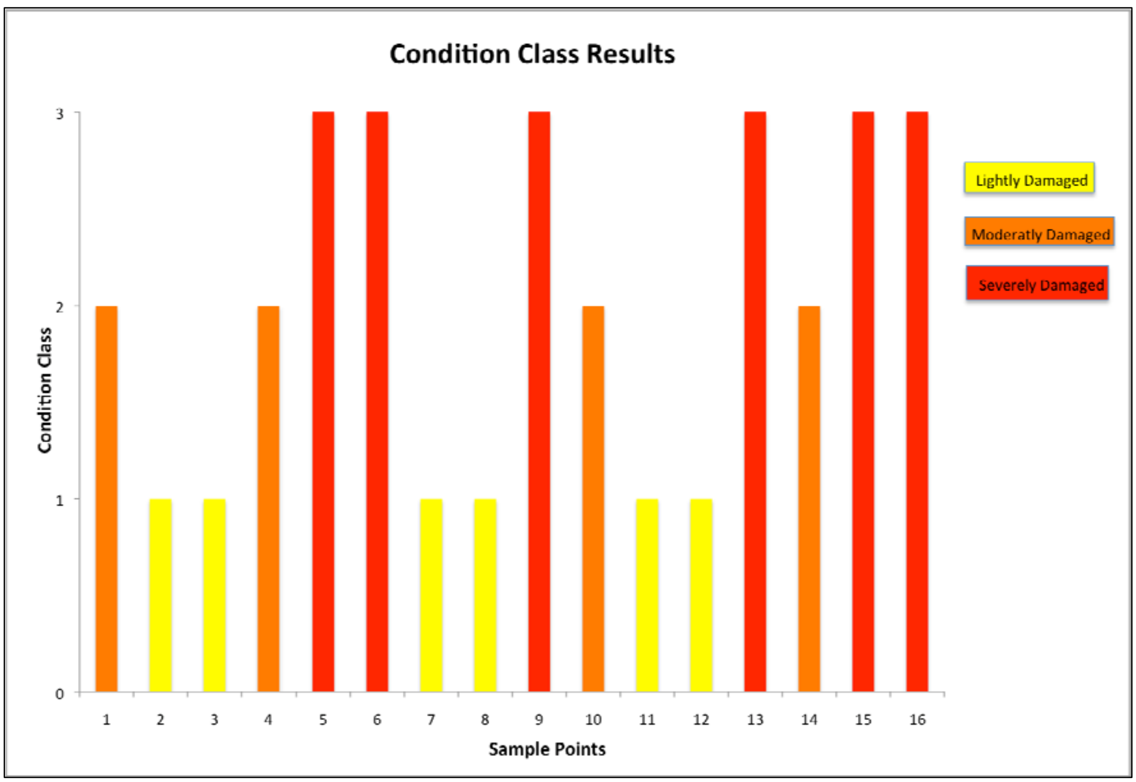

Figure 7. A histogram showing the results form the condition class model

6. Discussion

In order to assess the overall condition of the Hermit Trail all impact indicators measured were taken into account. Results from our trail condition class assessment were also used to determine a final rating. Findings revealed that the Hermit Trail, as a whole, is moderately degraded, particularly with regards to soil erosion, root exposure and the effectiveness of drainage ditches. To substantiate these findings, results were compared with previous studies. As the definition of “damaged” varied among studies, discrepancies were averaged and applied to site conditions.

The two indicators used to measure soil erosion were maximum incision and CSA. Many studies have found soil erosion to be a serious result of trail degradation and thus it has frequently been used as a key indicator in determining trail conditions (Marion et al, 2006; Garland, 1990). The mean maximum incision for the trail is 12.8 cm. According to Marion, 2006, an incision of 13 cm is considered severe, suggesting that 36% of our points our severely eroded. According to Cole, however, a depth of 25 cm is considered severe, suggesting that only (14.3%) of our points are in fact severely eroded. Regardless, these values represent a significant degree of soil erosion resulting in moderate degradation.

A more accurate measure of soil erosion is CSA. The mean soil loss for all sample points was 845.6 cm^2, with 7.1% of the points in excess of 1500 cm^2. The total estimated soil loss for the entire trail was 2.67 m^3. While this value does not seem large, the trail is relatively short (3.8 km), and this loss represents a significant “irreversible” impact once the soil has been transported off of the tread (Garland, 1990; Marion et al, 2006). This is of particular concern in alpine environments where soil production can take thousands of years (Dixon *et al.*,2004). The transport of eroded soil can also severely threaten water quality, especially in areas that are adjacent to streams and rivers (Marion, 2006).

Root exposure also played a large role in designating this trail as moderately damaged. One sample point (7.6%) exhibited extreme root exposure and five points (36%) were categorized as extensive, representing a relatively large portion of the trail. It should also be noted that the last 800 m of the trail, closest to the road, had vast amounts of root exposure. Even minor root exposure can cause significant environmental and social problems. Root exposure can be detrimental to surrounding vegetation leading to root damage and a reduction in plant health (Marion, 2006). It can also degrade trail aesthetic and become a safety concern for hikers (Marion, 2006).

Drainage features are important in preventing soil erosion and trail muddiness. The majority of drainage features encountered along the trail (66.7%) were found to be in medium or poor condition, with 45% classified as poor. These numbers suggest that the bulk of the drainage features are currently ineffective, thus leading to increased water erosion. The amount at which the water bars are filled with detritus underlines their importance and effectiveness in mitigating water erosion. Trails with high grades that run perpendicular to the contours are especially prone to water erosion, as runoff will flow directly down the trail. This leads to increased erosion rates via sheet and rill processes, and will deepen the trail depth resulting in "rutting". The high percentage of ineffective drainage features found on the Hermit Trail coupled with an average grade of 28.3% suggests a serious potential for erosion and thus a moderately degraded designation.

In terms of management it is important to understand the relationship between trail conditions and trail location as degradation can be minimized through proper trail design and maintenance (Cole, 1983). In our study we measured two inventory indicators: trail grade and grain size. Due to a small sample size we did not run any correlations to determine the effects of these two indicators on trail condition. Instead we used the results from previous studies to assume that certain relationships exist pertaining to slope and grain size.

Previous studies have found that a positive correlation exists between trail gradient and soil erosion, with steep slopes experiencing greater erovosity (Garland, 1990; Cole, 1983; Dixon et al, 2004 & Bratton et al, 1979). Another important indicator that we did not measure but is notably linked to trail gradient and erosion, is trail angle, which refers to the orientation of the trail to the prevailing slope (Marion, 2006). Low trail angles occur when trails more directly ascend the fall line of a slope, irrespective of its steepness (Marion, 2006). Trails with low trail angles have been found to be more susceptible to degradation, especially soil erosion. This is an important indicator that we did not measure, but should be considered in future studies.

The second inventory indicator measured was grain size. While the majority of trail assessment studies did not place a huge emphasis on soil properties it does play an important role in trail soil erosion potential. Literature directly relating grain size to trail degradation was very difficult to come by, however there are many studies that have found a correlation between grain size and soil erosion. A relationship was also found between soil texture and trail degradation, with treads classified as sandy having increased tread width and erosion (Marion, 2006). As stated previously, larger grain sizes are generally more resistant to erosion as they have better drainage and higher infiltration rates. In contrast, soils with small grain sizes (fine sand, silt or clay) have poor infiltration rates, so water has a tendency to pool on the surface or run down slope (Marion, 2006). With the steep grades associated with the Hermit Trail any water running down the trail, especially if the trail slope is high, would pick up speed leading to increased erosion. The Hermit Trail has a steep grade and a low slope alignment, so any water running down the trail will greatly increase erosion rates. In addition, the flatter sections found at the bottom of the trail could be at risk of increased muddiness, which has been found to lead to trail widening, amongst other problems.

In addition to the inventory indicators we measured, several others have been found to influence trail degradation. Marion (2006) found a relationship between topographic position (valley, mid-slope or ridge) and erosion rates, muddiness and trail width (Marion, 2006) with mid-slope trails exhibiting the greatest degree of erosion and valley trails being the muddiest and widest. Habitat or forest type has also been found to influence trail degradation, with different types of habitats exhibiting different degrees of degradation (Cole, 1983; Bratton et al., 1979). Both of these indicators are important aspects on the Hermit trail because it ascends through three different eco-regions (ICH, ESSF and alpine) associated topographic position.

Inventory indicators are important for trail management, as they can help to determine what factors led to certain degradation. For example, in areas with high degrees of soil erosion it is important to understand what factors (climate, gradient etc.) are contributing to erosion in order to mitigate the problem. If the majority of these areas have a high gradient and low slope angle then it can be assumed that these are the leading factors that need to be mitigated. These inventory indicators can also be used to predict and mitigate future problems. Managers can determine what areas are at high-risk for trail degradation based on inventory impact measurements. Preventative management can then be used to avoid those degrading impacts, which could save valuable resources and prevent ecological degradation in the future.

7. <u>Management Recommendations</u>

Management plans are the cornerstone of Parks Canada's commitment to the future. Such plans recognize the importance of providing opportunities for public enjoyment but stress the need for managers to seek ways to avoid or minimize ecological degradation (Parks Canada, 2008).

"The maintenance or restoration of ecological integrity, through the protection of natural resources and natural processes, shall be the first priority of the Minister when considering all aspects of the management of parks."

Canada National Parks Act, 2000

Visitor impact monitoring programs can assist managers in meeting these two objectives. This assessment of the Hermit Trail provides quantitative documentation of the types and extent of trail resource impacts. The following impact management practices are recommended for the Hermit Trail.

There is great potential for modifying the roles of use-related and environmental factors through managerial actions. Knowledge of the relationship between environmental factors and trail impacts is important, and can be applied to route trails in the most resistant and sustainable locations. Use-related factors can be influenced or controlled through education and regulatory actions. Trail construction and maintenance actions are also very important. Such actions could include the installation and upkeep of tread drainage features, rock steps, and bridging. These actions are vital to limiting soil erosion and tread muddiness, which in turn influence user behavior and the extent of other impacts such as tread widening (Marion, 2006).

7.1 Human Use Management

Glacier National Park was established in 1896 to provide recreational opportunities and to preserve and protect its resources. People are a fundamental part of the ecosystem, and the use and enjoyment of the national park generates significant social and economic value. As the number of visitors to the area increases, maintaining ecological integrity becomes increasingly challenging. Over the past decade, visitor traffic has grown by 1-2% annually and these numbers are expected to continue to increase. This situation calls for the development of strategies to manage visitor use for inspirational, educational, cultural, and recreational purposes at a level that will maintain the area in a natural or near natural state (Parks Canada, 2008).

Human use management is the direction and guidance of visitors and their use of the parks. It includes the management of visitor numbers, behavior, and activities, as well as the infrastructure and facilities they require. Human use management works to increase the quality of visitor experience while providing education to reduce use-related impacts (Parks Canada, 2008).

The Hermit Trail could benefit from an increased presence of human use management practices. Better signage is needed at the trailhead and at points along the trail. The sign at the trailhead should include a more detailed map of the hiking route, as well as consistent elevation, distance and time information. Information regarding the camping facilities at the summit of the Hermit Trail would also be beneficial for hikers. Additionally, we would suggest providing information about the three different eco-regions that hikers pass through when using the trail. This might motivate visitors to be more respectful of their environment, and would alert them to the fragility of the ecosystems. It would also provide a valuable educational experience. As the Hermit Trail is fairly challenging, we would recommend the park give the trail a difficulty rating. This system might be incorporated throughout the park. Along the trail, visitor experience could be improved by providing distance markers, or at least a halfway marker.

7.2 Environmental Management

There are certain indicators that can be explored to develop a framework for trail management. These include but are not limited to soil properties, water bar performance and frequency, trail corduroy, drainage dips, excessive grade and an establishment of sustainability indicators (Leung & Marion, 1999; Crabtree & Bayfield, 1998). The factors mentioned in the Universal Soil Loss Equation (1970) will be examined as to how to reduce the estimated soil loss from the Hermit trail. According to the extrapolation of the cross sectional area analysis, we determined that 2.67 m^2 was eroded from the trail tread. This estimate represents the direct removal of soil from the trail. It however, does not include soil creep, a slower form of erosion that is troublesome of trails in wet areas and steep hill alignment. As pressures are exerted on the trail, the bulk density decreases and the saturation level is easier to achieve. The water then lubricates the soil particles, causing the trail to gradually slide down hill. This could be mitigated by placing sheet drain on the uphill side of the trail with pipes at the bottom leading to the downhill side of the trail (see Figure 8). This will redirect groundwater flowing down hill, which, as it encounters soil with a higher bulk density, will saturate and potentially rise above the ground. This should allow the trail aggregates to remain dry in the face of considerable groundwater flow. Although we did not measure incidents of soil creep it was recognized throughout the Hermit trail through visual observation and should be considered in mitigation efforts.

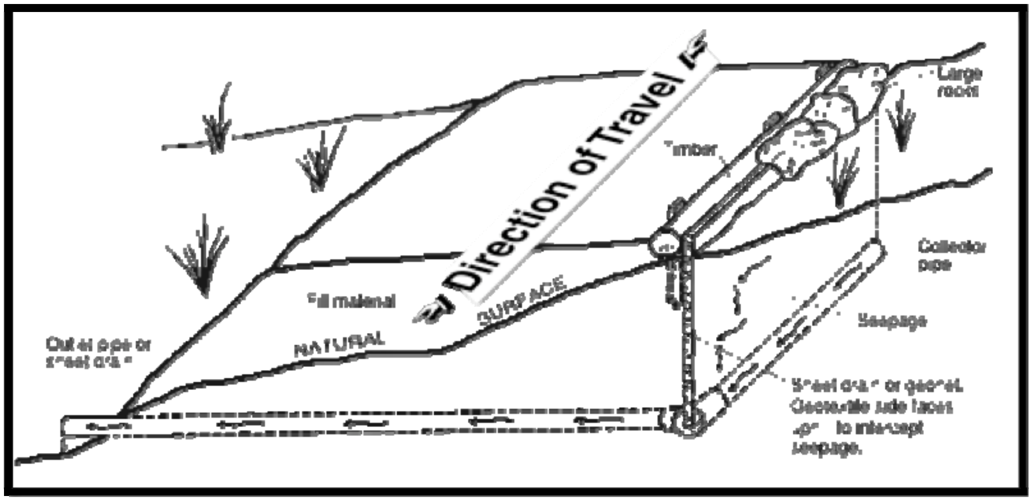

Figure 8. Diagram showing the use of sheet drain on the uphill side of the trail to mitigate soil erosion caused by soil creep.

Heselbarth and Vachowski (2000) have established criteria for the construction of sidehill trails. If a trail is being built along a slope that is less than 10% then you simply need to remove the organic litter and expose the mineral soil underneath. If the slope the trail is being built along is between 10-30% then a half bench design should be employed. This is where half of the slope is dug out for the trail and the remainder is composed of compacted mineral soil dug from the up slope. If the trail exceeds 30% then a three-quarter or full bench design should be employed to minimize the amount that the trail slips. A properly constructed sidehill trail will mitigate the most common effects of trail degradation problems: tread erosion, muddiness, widening and secondary treads (Agate, 1996; Demrow& Salisbury, 1998). If trail reroute is required on steep sections then it is recommended that they follow the criteria established by Heselbarth and Vachowski

The trail itself can act as a rill, accumulating increasing amounts of water as it descends. This gathering of water can be detrimental to mitigating soil erosion. To rid the trail of water two common drainage features are employed: water bars and grade dips. In our study we recorded the number of water features found within each eco-region and their associated condition (Table 5). The total number of drainage features found along the trail was 129. Unfortunately the type of drainage feature, water bar or grade dip, was not recorded at the time.

Table 5. Condition and number of drainage ditches recorded within each eco-region along the Hermit trail, GNP, BC.

Eco-region	Good Condition	Medium Condition	Poor Condition	Total
Interior Cedar Hemlock	10	9	34	53
Engelmann Spruce and Subalpine Fir	22	15	21	58
Alpine	12	4	2	18
Total				129

The placement of these drainage features is crucial and should be determined by slope, soil type, and precipitation levels, which are generally associated with eco-region. The ICH eco-region has a mean annual precipitation of 1000-1700 mm, the ESSF eco-region has the highest level of precipitation (1700 to > 2100 mm) and the alpine eco-region receives the smallest proportion of precipitation. Numbers for the mean annual precipitation for the alpine eco-region were unavailable but the ecological land classification of GNP (1984) states that the trend of increasing elevation and increasing precipitation reverses in the alpine. The construction of drainage features on the Hermit trail represents this trend with the highest proportion of drainage features in the ESSF eco-region followed by the ICH and finally the lowest amount of water bars in the alpine eco-region. It should be noted that while conducting this survey our position within the eco-regions was merely an estimate based on surrounding vegetation. As stated in the Ecological land classification of GNP, vegetation of an ecosystem reflects elevational controls on climate. By this basis our recordings should be fairly accurate. The establishment of water bars according to precipitation levels is appropriate for the trail. Unfortunately, (Hasselbarth and Vachowski, 2000) state that water bars and associated drainage ditches should be maintained one to three times a year. The poor condition of the majority of water bars shows that there needs to be increased maintenance of these features.

Another factor that was not taken into account was soil wetness. Although this will vary seasonally, the vast majority of precipitation occurs in the winter as snow and then in the spring as it melts. This means that at the time of the study highly effected areas were not apparent. Troublesome areas should be addressed so that trail experiencing, muddiness and runoff do not become problems. This could explain why stretches of the trail running through the ESSF and ICH eco-regions are on average wider