TUNDRA TRAVEL RESEARCH PROJECT: VALIDATION STUDY and MANAGEMENT RECOMMENDATIONS

A Project Prepared for the

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By

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ABSTRACT

In October 2004 the Alaska Department of Natural Resources published a model that used experimental plots to predict changes in important environmental variables caused by winter oil and gas exploration on tundra surface resources. The objectives of this report are to:

1. Validate the study results in real-world conditions
2. Continue monitoring the experimental plots to determine if degradation or recovery trends change over time.
3. Design a visual assessment system to assist staff to make preliminary determinations of disturbance during summer field inspections of exploration activity.
4. Make recommendations regarding management standards.

First, observations from this final validation phase of the project indicate that the standard, derived from the model prediction, resulted in preventing significant environmental change as a consequence of overland vehicle travel pursuant to hydrocarbon exploration under actual working conditions. Indeed, based upon the 2005 validation results, it appears the standard may exhibit a conservative

bias in favor of environmental protection. This conservative bias in the results is consistent with the "precautionary principle" which is an appropriate strategy for decision-making in the context of arctic management.

Second, no delayed effects, nor trends toward increasing disturbance intensity, were observed the second year after treatment on the experimental plots. Indeed, the trend seems to be toward a return to the natural range of variation among the key indicator variables used in the study. This would suggest rather robust resiliency at the relatively low levels of disturbance recorded as a result of the experiments.

Third, a quick and efficient tool for visual estimations was successfully developed for use by DNR staff. This system employs 250-meter segments of trail to ascertain disturbance not readily detected by the more quantitative and objective measurement approaches.

Finally, the report recommends that prior to approval of overland tundra travel by vehicles, that the soil temperature within the first 30 cm of depth be no warmer than –5 degrees Centigrade, and that a minimum of 15 cm of cover snow be present in wet sedge tundra environments and a minimum of 23 cm of cover snow in tussock tundra environments.

Under these conditions, tundra disturbance should be minimal. For those disturbance effects that do transpire, the resiliency of the tundra ecosystem, as indicated by the plot monitoring (as well as reported in the scientific literature), is likely to be such that recovery towards pre-disturbance conditions are expected to be relatively rapid.

INTRODUCTION

This report represents the second and final product of a three-year study initiated by the Alaska Department of Natural Resources in cooperation with the U.S. Department of Energy, Yale University School of Forestry, and the Alaska Oil and Gas Association. The goal of the overall study was to: (1) identify those environmental factors which contribute toward resistance of tundra systems to disturbance caused by hydrocarbon exploration; (2) generate appropriate management standards which would promote protection of arctic tundra while allowing exploration activity; and (3) develop monitoring protocols that empower the agency to readily determine if management goals are achieved.

The study designed and implemented the first ever standardized and controlled scientific field experiments to generate empirical data related to tundra disturbance following winter overland travel by heavy vehicles. The study is prompted by the impact of changing climate trends on exploration activity. These trends substantially shorten the winter exploration window during which time the ground was sufficiently frozen and covered with snow to permit travel across the tundra by heavy vehicles used in exploration. A detailed description of the study design and findings is found in the first report, released by the state in November 2004 entitled "Tundra Travel Model Study." This second report details the validation studies following the initial findings and must, therefore, be read and interpreted in conjunction with the first report.[1]

The first report successfully identified those factors which contributed to disturbance resistance, as well as those variables which managers could rely upon to ascertain the existence and intensity of disturbance quickly, and at low

[1] Descriptions of study results, tundra features, technical terms, seismic exploration, disturbance theory and ecological processes important to this study are contained in the first report and will not be repeated here.

administrative cost in fiscal, temporal, and personnel resources, for management purposes. This second report follows research validating the initial findings and proposes objective, quantitative standards for both implementation and monitoring of hydrocarbon exploration activity.

Following the first 2 years of the study, DNR generated a model (described in Report #1) which the agency used to predict the ideal set of snow and frozen ground conditions under which no significant disturbance would be observed if exploration activity were to take place. Because the model was generated pursuant to an empirical study under controlled field conditions, DNR recognized the necessity to validate the results. Therefore, during the winter of 2004-05, these predictions were tested under routine activity as conducted by geotechnical companies in the normal course of actual seismic exploration. Tundra disturbance was then evaluated to determine the success of the prediction during the summer of 2005. DNR also continued to monitor the original study plots to determine if new or additional disturbance trends were observed and to modify the model if necessary. Finally, DNR developed a standardized system of ocular estimation for rapid field verification of disturbance and tested this system against known disturbance patterns in the original study plots that were treated in 2003-4. Thus, this report addresses the: (1) field validation study, (2) second year monitoring program, and (3) visual field evaluation system.

FIELD VALIDATION STUDY

Prior to formal implementation of management standards created from results produced by the modeling study, it is imperative that the prediction be tested in the field under the conditions of actual exploration practices. Therefore, DNR designed a validation study to test whether exploration activity would induce environmental changes different than that of control plots where no such activity took place.

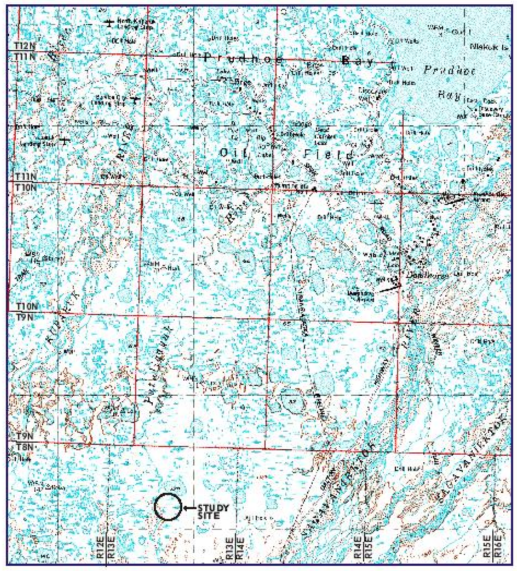

Figure 1.
VALIDATION STUDY SITE LOCATION

Site Selection

In collaboration with Veritas, a Canada based seismic exploration company, DNR selected a winter validation study site. The site is located approximately 11 miles south and 9 miles west of the Deadhorse, Alaska airport (Figure 1). The site was selected on the basis of five criteria: (1) the area had to be scheduled for exploration in the winter of 2004-2005; (2) relatively close proximity to the Dalton highway to permit DNR personnel to utilize snow machines to access the sites without undue danger to staff safety in midwinter; (3) sufficient topographic variability to generate vegetation diversity in addition to the ubiquitous wet sedge tundra so characteristic of the coastal plain; (4) proximity to ground temperature monitoring stations established by the University of Alaska; and (5) the area had to be free of prior disturbance. These criteria were satisfied at the selected site. Maximum distance to be traveled by snow machine from the road was 15 miles in mid-winter, the area was scheduled for exploration during the first week of January, the site contained areas of tussocks and moist sedge/shrub tundra as well as the dominant community of wet sedge meadow, and no visual evidence of “green trails” were present in a preliminary over-flight the previous autumn.

The validation study site is characteristic arctic coastal plain. Winters are cold, precipitation low, (most of which is contributed as snow), and cool, cloudy summers. Considerable standing water is present in the nearly level terrain, particularly in areas of patterned ground including the margins of high-center polygons and the middle of low center polygons. Frost boils, patterned ground, and hummocks were found within the site and traversed by the study transects. The study site is frequently grazed by caribou in summer and occasionally by musk ox in winter.

Transect Location:

Seismic exploration can cover well over 1000 square miles of territory in very remote locations and require significant logistical support under conditions regarded as a trade secret to be kept from rival companies. Consequently, DNR entered into a confidential agreement with Veritas to receive 1000 “intersection point” GPS coordinates.

An intersection point is that location where both a “receiver line” and a “source line” meet. These points must be accurately determined in advance to within a few centimeters to ensure the quality of seismic data collected by the companies engaged in exploration.

Seismic exploration involves the use of very large and heavy equipment traveling across the tundra. Vibrators are track vehicles that contain a pedestal that vibrates at high rpm against the ground to generate an echo that travels through the ground and bounces off various geological formations before returning back to the surface. Thus, the vibrator vehicles create the “source lines.” Vibrators create a shockwave traveling through the earth much like a sonar wave through the ocean.

Receiver lines consist of many miles of geophones (microphones) that are laid upon the ground by lighter track vehicles and later recovered. These receiver lines feed into mobile laboratories. The laboratories are situated on large sleds with skids and pulled by caterpillar tractors.

All source lines must be parallel to one another as must the receiver lines. The two sets of lines intersect one another at a prescribed angle on a standard interval to create a giant grid pattern. In a typical work season, a seismic operation may create more than 2,000 miles of combined source and receiver lines, covering many hundreds of square miles. A typical "intersection point" will receive a single pass by a vibrator and two passes by vehicles laying out and then picking back up the receiver lines. Occasionally, the points may also be crossed by crews sent to repair damaged vehicles or to trouble shoot problems with the receiver line.

In addition to the source and receiver lines, seismic exploration involves camp moves where whole cities of staff are moved, housed, fed, and work in buildings resting upon sleds that are periodically moved as the process proceeds in an inchworm fashion across the arctic tundra. Camp move trails typically involve less than 120 miles of trail.

Because the grid created by the combined source and receiver lines occur at a landscape level, potentially affecting 100,000's of acres annually, the DNR study focuses upon impacts associated with these lines as the most likely source of significant and widespread ecological disturbance. Camp move trails, due to their limited length, are ignored in the study. However, DNR recognizes that the disturbance associated with camp moves is very likely to be far more intense than that of the seismic lines, due to the multiple passes by many sleds, pulled by caterpillar tractors having steel cleats.

In order to ensure that the seismic operators were unaware of the locations of the transects for the validation study, DNR sent staff to select 12 intersection points from among the 1000 and establish both control and treatment transects. Treatment transects were located in an east west orientation with the center of each transect located directly over the intersection point. This ensured that each treatment transect would be traversed by both a source and receiver line. Two control transects were established for each “intersection point.” Each control transect was oriented in a north-south direction with the center points approximately 30 meters from the “intersection point,” with one control transect at 135 degrees(southeast) from the intersection and the other at 320 degrees (north-west) from the intersection (Figure 2). All transects were left unmarked so as not to alert seismic crew of their location. Blowing wind and snow obscured all trace of the measurement work by the time crews came in contact with transects, approximately 24 hours later. This layout of control and treatment intersections is intended to prevent control transects from accidentally being effected by treatments (it should be noted that this design was successfully tested and used in a DNR precursor pilot study during the winter of 2002 in a similar area).

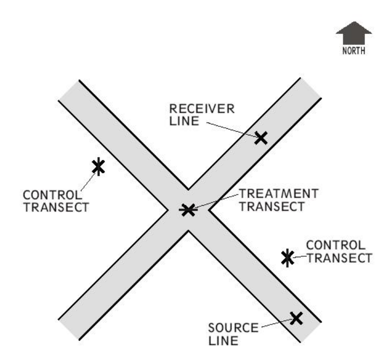

Figure 2.
VALIDATION STUDY TRANSECT PLACEMENT

Measurement Methodology

During the first phase of the study (discussed in Report #1) DNR evaluated 9 different environmental variables that could be used as indicators of ecological disturbance. The variables found to best serve as key indicators of disturbance were: (1) change in depth of active layer and (2) soil moisture content. These variables seemed to respond most quickly to disturbance stressors, were susceptible to quantitative and objective measurement techniques, as well as being easy, quick and inexpensive to measure, thus making them ideal as indicators for management use.

The environmental characteristics found by the study to contribute to disturbance resistance were the depth of the overlying snow, the hardness of the ground[2], and the formation of a snow slab. Also important was whether the ground traveled across was primarily vegetated with wet sedge meadow tundra or tussock tundra.

The day before the seismic crews were scheduled to begin work (December 30, 2004) in the sector containing the study "intersection points," DNR staff traveled by snow machine and surveyed in the transects and collected snow depth, snow slab thickness, and ground hardness data. Measurements were taken in strict adherence with the winter measurement protocols outlined in Report #1.

Two months later, after completion of the seismic survey, DNR staff then returned to the site by Haagland track vehicle to re-survey and mark transect locations with metal rods pounded into the frozen ground. DNR made a survey grade quality relocation within an accuracy of 3 cm for each transect. The

[2] DNR later substituted ground temperature along a 30 cm deep profile for ground hardness in the model. Temperature replaced ground hardness measurements for four reasons: (1) use of temperature instead of ground hardness marginally increased the r-square value of the model; (2) when both temperature and ground hardness were included in the model, ground hardness dropped out as a significant input variable, while soil profile temperature remained significant; (3) temperature had lower variability than hardness measurements and (4) temperature is an easier characteristic to collect with superior precision. Soil profile temperatures were collected from a University of Alaska research site located near Deadhorse airport.

Haagland represented an additional pass over the "intersection points, imposing the potential of greater disturbance than that which would be anticipated under routine exploration operations.

In July of 2005 DNR flew by helicopter to the validation transects. Measurements for depth of active layer and soil moisture were taken at all control and treatment transects in strict adherence with the summer measurement protocols for these characteristics as described in Report #1.

Modeling Prediction

The DNR study anticipated that a snow cover of 15 cm and a ground soil temperature of -5 degrees C throughout a 30 cm deep soil profile would ameliorate the effects of cross country travel over sedge dominated tundra by exploration equipment. DNR anticipated that disturbance changes as a result of the vehicles would be indistinguishable from the normal range of inter-annual variation on undisturbed sites. Under the conditions found during the December 30, 2004 measurements, DNR predicted that the summer 2005 depth of active layer would be 34 cm and the soil moisture would be 80 percent and that no significant differences would be detected between the treatment and the control transects.

As previously mentioned in footnote 2, DNR substituted ground temperatures along a 30 cm deep soil profile for ground hardness readings because such readings contributed superior qualities to the model. As a result, all further modeling and monitoring by DNR now uses buried soil temperature measuring devices that can be read by staff in the field to gauge ground temperatures.

In the period just prior to the zero curtain point (see Report #1), when the latent heat of water is released as soil moisture freezes[3], DNR anticipates that soil

[3] Outcalt, S.I., Nelson, F.E., and Hinkel, K. 1990. Zero curtain effect: heat and mass transfer across an isothermal region in frozen soil. Water Res. Research 26(7) 1509-1516. Hinkel, K.M., Paetzold, F.

temperatures may vary markedly from site to site, depending upon local soil moisture content. The more moisture, the longer the period of the zero curtain effect.

Thus, in early winter when soil profile temperatures hover between +1 C and –1 C, one would expect considerable variability in soil temperature readings along the profile. This variability would continue until the temperature across the landscape had dropped sufficiently below the zero curtain point. At that time, soil temperatures at a landscape level would be most influenced by local topography and the insulation qualities of differential snow cover rather than soil moisture content. The decrease in soil profile temperature variability over time, as winter progresses, would be consistent with the decrease in soil hardness variability from early to mid winter as observed by DNR and reported in a prior study.[4]

Winter Measurements

At the time of exploration equipment travel over the validation site, DNR found an average snow depth of 19 cm and a ground temperature of -8 C at the soil surface, -7.5 C at a 15 cm depth, and -7 C at a 30 cm depth.

Validation Study Analysis and Results/Summer Measurements

DNR found no statistically significant differences (p=0.05) between treatment transects (where vehicles passed over them) and control transects (where no vehicles passed) at the validation site. (See Figures 3a and 3b). Treatment depth of active layer was found to be 35.5 cm +/- 3.4 cm at a 95% CI (n=132; standev=19 cm). Treatment transect soil moisture was 82.8% +/- 3.5% at a 95% CI (n=72; standev= 15%). Control transect depth of active layer was 33.9 cm +/- 1 cm at a 95% CI (n=264; standev=8.5 cm). Control transect soil moisture was 84.4% +/- 2.6% at a 95% CI (n=144; standev=40.4%).

Nelson, F.E. and Bockheim, J.G. 2001. Patterns of soil temperature and moisture in the active layer and upper permafrost at Barrow, Alaska. Global and Planetary Change 293-309.

[4] Bader, H.R. and Mark Wishnie. 2002. Internal DNR Report on Slide Hammer Use for Measuring Tundra Resistance to Disturbance. (Unpublished).

DNR employed a standard two-tailed T-test to compare control and treatment means for depth of active layer and soil moisture. Data were normally distributed with sufficient similarity in variance to permit this parametric test without data transformation.

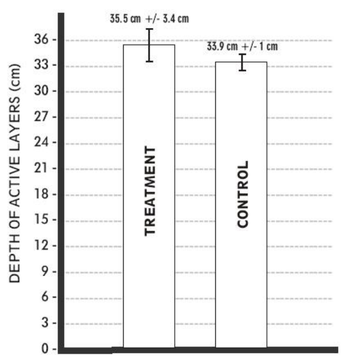

Figure 3a.
VALIDATION STUDY
DEPTH OF ACTIVE LAYER

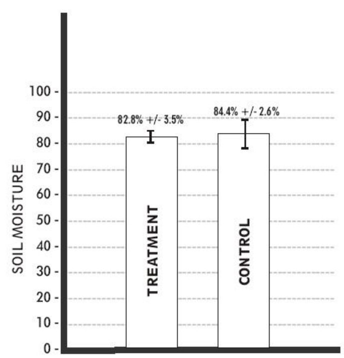

Figure 3b.
VALIDATION STUDY
SOIL MOISTURE AT 15 cm DEPTH

POST TREATMENT MONITORING PROGRAM RESULTS

DNR recognizes that ecological disturbances may require a period of time before indicators of change manifest.   Therefore, DNR has engaged in a long term monitoring program of the original test plots examining change trends which may indicate unanticipated consequences of the treatments over time. Measurements taken in the summer of 2005 at the experimental plots represent this program. The full suite of characteristics, as identified in Report #1, were re-measured in 2005.

For the purposes of this study, as explained in Report #1, disturbance is defined as a change in base line that exceeds that observed for natural inter-annual variation for each of the measured characteristics. Thus, the technique used by

DNR to find disturbance is to compare the change in No Treatment plots, from 2003 to 2005, and compare them to the changes observed between 2003 to 2005 in the Treatment plots. For example, if change in a "No Treatment" plot for depth of active layer is 3 cm, it is compared to the change for each treatment type and test period between 2003 and 2005. If a Treatment plot recorded a change of 7 cm, a test would be performed to determine if the difference in base line change between treatment plot and no treatment plot were statistically significant or not.

DNR found, in Report #1, statistically significant changes in soil moisture and depth of active layer in those plots traveled by a tractor when ground profile temperatures were warmer than -5 degrees C and snow depth was less than 15 cm in the wet sedge tundra and less than 23 cm in tussock tundra. The 2005 monitoring measurements found resiliency in these same plots with the difference in change between Treatment and No Treatment plots converging (See Tables 1 and 2).

Sedge tundra no longer exhibited statistically significant differences in change from base line between Treatment and No Treatment plots. Statistically, significant differences for change in both depth of active layer and soil moisture were present in the tussock tundra tractor plots of the foothills.

However, the actual and relative differences in depth of active layer between Treatment and No Treatment plots located in tussock tundra on the Foothills study site in 2005 declined from that found in 2004. (See Table 2). The difference in change in soil moisture between treatment and no treatment, while greater in 2005, was toward a drier condition. This trend toward a drier condition is less problematic to managers than the reverse, from an ecological disturbance perspective. The scientific literature identifies greater soil moisture as a condition that exacerbates thermal erosion, because of the ability of water to absorb energy and transport it efficiently through the soil profile. Thus, the change from a more wet condition the first year following the treatment, to a slightly drier condition in 2005, indicates a trend which seems to alleviate the fear of accelerated disturbance intensity (See Report #1 for details from the published literature for a fuller explanation of tundra disturbance). Continued monitoring of these plots is warranted, in light of the inconclusive results regarding soil moisture change in the Foothills tussock terrain.

Table 1:Disturbance Characteristics 2003 to 2005 for Selected Plots

Location	Characteristic	Treatment Type/Date	Year 2003	Year 2005	Change from 2003 to 2005	Difference from No Treatment
Coastal Plain	Depth of Active Layer	No Treatment	44.6 cm	47.5 cm	-2.9 cm	N/A
Coastal Plain	Depth of Active Layer	Tractor/1	56.3 cm	55.7 cm	-2.1 cm	0.8 cm
Coastal Plain	Soil Moisture	No Treatment	83 %	74.6 %	-8.4	N/A
Coastal Plain	Soil Moisture	Tractor/1	81 %	72.6 %	-8.4	0 %
Foothills	Depth of Active Layer	No Treatment	17.2	20.5	-3.3	N/A
Foothills	Depth of Active Layer	Tractor/1	17.4	25.4	-8.0	4.7*
Foothills	Soil Moisture	No Treatment	50.2	34.6	-15.6	N/A
Foothills	Soil Moisture	Tractor/1	56.0	32.2	-23.8	8.2*

NOTE: * denotes a statistically significant departure from natural baseline change.

Table 2: Treatment Plot Departure from Natural Change by Year and Location

Location	Treatment Type & (Date)	Departure from Natural Change in 2004	Departure from Natural Change in 2005
Coast Depth of Active Layer	Tractor (1)	2.5 cm deeper	0.8 cm shallower
Coast-Soil Moisture	Tractor (1)	7% lower	0% difference
Foot Hills-Depth of Active Layer	Tractor (1)	5.6 cm deeper	4.7 cm deeper*
Foothills-Soil Moisture	Tractor (1)	3.7% higher	8.2 % lower*

NOTE: * indicates statistically significant departure from natural baseline change

Based upon these findings, DNR is confident that no new manifestations of disturbance type or trend have developed on the study plots. Therefore, DNR does not anticipate new disturbance indicators. However, DNR shall continue to take monitoring measurements in accordance to the established long-term program.

VISUAL ASSESSMENT TECHNIQUE

Objective and quantitative field measurements are essential to confirm disturbance type and intensity for effective management. However, these approaches are both labor intensive and expensive, as well as logistically difficult. To first determine if the investment in field measurement is warranted, a system of quick, cheap and easy disturbance evaluation is needed. As a result, DNR tested a number of quick ocular estimate techniques that could be used to identify and characterize disturbance levels.

DNR field personnel working on the study in 2004 and 2005 noticed that visual changes were present in test plots that were not necessarily manifested within the transects. To determine if ocular estimations could be reliably used as an additional tool to describe disturbance, DNR embarked upon development of procedures for use to make a standardized approach for visual disturbance evaluation. This visual assessment system is not intended to determine changes of ecological consequence; rather, the visual assessment is intended to augment the more labor intensive science based measurements described above. Such an approach may be most useful for quickly evaluating a large area.

The DNR Visual Assessment system is based in part upon the pioneering research of the U.S. Fish and Wildlife Service (USFWS) in the Arctic National Wildlife Refuge.[5] The USFWS system used a three-tiered approach characterizing disturbance as high, moderate, and low based upon damage to surface vegetation and the soil surface. (The USFWS system is described in detail in Report #1 and will not be repeated here.)

As mentioned in Report #1, the maximum disturbance level produced by the DNR field tests during the winter of 2003-4 did not exceed that which the USFWS system would characterize as LOW. However, even this low level of disturbance (which occurred in plots traveled by either tractor or challenger under conditions where soil temperatures were warmer than -5 degrees C and snow cover was less than 15 cm, see Report #1) exceeds that which DNR stewardship finds acceptable. Consequently, the DNR Visual Assessment System used plots where statistically significant disturbance was observed as the definitional threshold demarcating permissible management, even though these plots could be described as low level disturbance under the USFWS classification system.

[5] See: Emers, M., Jorgenson, J.C. 1995. Response of arctic tundra plant communities to winter vehicle disturbance. Can. J. bot. 73:905-917; See also: Felix, N.A., Raynolds, M.K., Jorgenson, J.C. and Dubois, K.E. 1992. Resistance and resilience of tundra plant communities to disturbance by winter seismic vehicles. Arct. And Alp. Res. 24:69-77.

Such an approach is consistent with the precautionary principle, which is an appropriate management approach for land stewardship in the somewhat fragile arctic environment.

The DNR Visual Assessment System grew out of modifications from techniques studied during the 2005 summer field season. It employs a qualitative and subjective approach of ocular estimation that ranks vegetation and soil disturbance as a percent of total surface disruption per unit length of seismic trail. The unit of trail length is approximately 250 meters long (derived from the average length of each figure 8 in the treatment plots). Two disturbance characteristics are used. One indicator is vegetation damage, the other is presence of surface displacement or depression (rutting). Vegetation damage is defined as any visible mechanical alteration of vegetation anatomy such as broken or abraded branches of shrubs and scuffed or crushed tussocks. Soil surface displacement is defined as any visually discernable depression or displacement of soil giving rise to a definable track. It must be noted that green trails (as discussed in Report #1, are not considered disturbance in this technique).

Each linear meter of the 250 meter length of trail is tallied separately to determine if either vegetation or soil surface disturbance is present. Then the total number of meters for each disturbance variable is summed separately and the percentage of trail with vegetation disturbance and the percentage of trail with soil surface disturbance is determined.

A rank of 1, 2, or 3 is then assigned to describe each disturbance characteristic (See Table 3) based upon the percentage of trail altered. Once the observer has assigned a rank for each disturbance characteristic, the two numbers are multiplied together because it is assumed that these two characteristics are interactive with one another, giving rise to a change in environment greater than each individually. Thus, a rating system of 1-9 is created.

Table 3: Assessment Score

Rank Score	Percent Trail Surface with Vegetation Damage	Percent Trail Surface with Soil Displacement
1	0-2	0-2
2	3-4	3-4
3	5 or greater	5 or greater

Each plot on the foothills treatment study site[6] was then ranked independently by three different DNR staff. The DNR staff responsible for assigning rank values were not informed as to the treatment type or date of each plot so as to avoid anticipatory bias in the assignment of values.

After values were assigned the rank scores were compared among the staff to determine consistency. Congruency among the three staff rankings was exceptional. All three staff assigned exactly the same values to 26 of 30 plots, with the remaining plots receiving identical values by two of the three staff. In addition, the ranking system was consistent with overall disturbance values found on the plots as would be expected from the treatment type and treatment date (Table 4).

Table 4: Rapid Assessment Rank Scores by Treatment Type and Date

Treatment Date	Tractor	Challenger	Loader	Tucker	No Vehicle Treatment
Oct 30	9	9	3	1	1
Nov 14	9	6	1	1	1
Dec 3	6	4	1	1	1
Dec 16	4	3	1	1	1
Jan 5	3	3	1	1	1
Jan 20	2	1	1	1	1

[6] The foothills study site was selected because it had the most easily identifiable disturbance patterns, which could also be employed in sedge tundra terrain.

The congruency of the rankings among different staff, coupled with the consistency of the ranking system results with plot disturbance measurements, suggests that this technique may prove a useful tool in the field as a preliminary approach for quick evaluations to determine if intensive field measurements are warranted. If quantitative field measurements are deemed necessary, DNR can implement monitoring protocols similar in methodology to the summer measurements taken for the validation study.

Because no distinction is made between severe or low level disturbance for each characteristic in a particular meter of trail length, a conservative bias resulting in over estimating disturbance is built into the visual evaluation system. Again, this approach is consistent with a precautionary principle, and appropriate for management of fragile, and little understood environments.

CONCLUSIONS AND RECOMMENDATIONS

The 2004-05 season follow up study appears to validate the prediction that employing a standard based upon a minimum snow cover of 15 cm, and a 30 cm deep soil profile temperature of -5 degrees C or colder[7], is sufficient to ameliorate ecological disturbances in wet sedge tundra environments. Ecological disturbance is defined for purposes of the validation study as a departure from natural base line change in two key indicator characteristics. The characteristics used are: (1) change in depth of active layer and (2) change in soil moisture. While not specifically tested, the prediction that 23 cm of snow is sufficient to protect tussock dominated tundra from disturbance seems reasonable, given the observations in the foothills study plots, tussock disturbance measured in the validation study, and from information contained in the scientific literature.

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[7] The temperature should be at least –5 degrees C throughout the entire 30 cm depth of the soil profile. DNR uses three temperature sensors arranged at depths of 10 cm, 20 cm, and 30 cm to get the total profile temperature. Each sensor at the three depths for each profile must read –5 C or colder to meet this condition.

Therefore, it is the recommendation of this study that DNR:

(1) implement the 15 cm snow cover/-5 degree C or colder 30 cm deep ground profile temperature standard for sedge tundra;
(2) implement a 23 cm snow cover/-5 degree C or colder 30 cm ground profile temperature standard for tussock tundra;
(3) continue long term monitoring of the coastal and foothills study sites to evaluate if new disturbance trends or types become apparent;
(4) monitor field observations to ensure that actual results continue to remain consistent with anticipated results;
(5) adopt the visual assessment technique for initial field verification of seismic line disturbance; and
(6) discontinue use of the slide hammer in favor of temperature arrays in ascertaining appropriate ground conditions for tundra travel (i.e. adopt the objective –5 centigrade standard and forego the more subjective “ground hardness” estimate associated with use of the slide hammer.