Keeyask Generation Project

Terrestrial Effects Monitoring Plan

Road Dust on Vegetation Monitoring Report

TEMP-2021-06

KEEYASK

Manitoba Conservation and Climate Client File 5550.00
Manitoba Environment Act Licence No. 3107

2020 -2021

KEEYASK GENERATION PROJECT

TERRESTRIAL EFFECTS MONITORING PLAN

REPORT #TEMP-2021-06

ROAD DUST ON VEGETATION MONITORING

Prepared for

Manitoba Hydro

By

ECOSTEM Ltd.

June 2021

This report should be cited as follows:

ECOSTEM Ltd. 2021. Keeyask Generation Project Terrestrial Effects Monitoring Plan Report #TEMP-2021-06: Road Dust on Vegetation Monitoring. A report prepared for Manitoba Hydro by ECOSTEM Ltd., June 2021.

SUMMARY

Background

Construction of the Keeyask Generation Project (the Project) at Gull Rapids began in July 2014. The Keeyask Hydropower Limited Partnership (KHLP) was required to prepare a plan to monitor the effects of construction and operation of the generating station on the terrestrial environment. Monitoring results will help the KHLP, government regulators, members of local First Nation communities, and the general public understand how construction and operation of the generating station will affect the environment, and whether or not more needs to be done to reduce harmful effects.

This report describes the results of monitoring road dust on plants in 2020, which was conducted during the seventh summer of Project construction.

Why is the study being done?

While conducting terrestrial habitat fieldwork in 2016, heavy dust accumulation on plants was observed in areas more than 100 metres from the North Access Road. If road dust was accumulating at many locations along the main Project access roads that were more than 100 m from the roads, then there was a small chance that Project effects on terrestrial habitat and ecosystems could be higher than predicted in the Environmental Impact Statement (EIS). Also, members of the partner First Nations had expressed concerns about high levels of road dust along the South Access Road during the early years of Project construction. These observations led to this new monitoring study, to confirm predicted effects of road dust from the Project on plants.

Road dust on plant leaves near a Project access road

What was done?

Information for this study was collected in stages. During Stage 1, information was collected in summer 2018 at locations that were 100 metres or further from the North and South Access Roads to document how far dust is travelling from these roads, and to document possible effects on plants.

The results of Stage 1 field studies were used to help design Stage 2 studies, which were conducted between July 23-27 and August 14-17, 2020. Information on plant health was collected along 22 transects along the North Access Road at sites 50 metres or further from the road.

Dust data was not collected in 2020 because it rained too often during July and August for dust to accumulate. This was not a major complication for this study because its main focus is on determining if road dust is having a negative effect on plants, and this evaluation is based on leaf condition.

What was found?

The monitoring found that leaf health declined over the growing season.

The monitoring did not find any apparent trends in increasing leaf health with distance from the road. This was the case for all of the overall measures used, and for individual plant species. For example, average leaf mortality and damage showed no decreasing effect from the locations closest to the roadbed to the locations farther from the roadbed.

What does it mean?

The decline in leaf health over the growing season was expected as it is something that occurs naturally.

Results from this study did not find any evidence to suggest that road dust has negatively affected plants in areas more than 100 m from the Project access roads.

There were no statistically significant, or even suggestive, decreasing trends in leaf health with increasing distance from the road for any of the plant information gathered. This included leaf health, the overall average of the maximum percent of affected leaves in each site, the average number of species with leaf mortality, and leaf mortality and damage for individual species.

What will be done next?

This monitoring study is now concluded as there was no evidence to suggest that Project road dust effects on vegetation were greater than assumed in the EIS.

ACKNOWLEDGEMENTS

ECOSTEM Ltd. would like to thank Rachel Boone, Sherrie Mason and the on-site Manitoba Hydro staff, including Kim Bryson, Megan Anger and Linda Campbell for their support and assistance in planning field activities. Rachel Boone and Sherrie Mason are also gratefully acknowledged for coordinating the terrestrial monitoring studies.

Chiefs and Councils of Tataskweyak Cree Nation (TCN), War Lake First Nation (WLFN), York Factory First Nation (YFFN) and Fox Lake Cree Nation (FLCN) are gratefully acknowledged for their support of this program. We would also like to thank Terry Kitchekeesik of TCN for arranging logistical support and providing field staff for studies.

We would also like to thank North/South Consultants Inc., in particular Ron Bretecher, Regan Caskey and Shari Fournier for their guidance, logistical support and other resources that made these studies possible.

STUDY TEAM

Dr. James Ehnes was the project manager and study designer.

Fieldwork was conducted by Brock Epp, Nathan Ricard, Alex Snitowski, Alanna Sutton and Barry Flett (TCN).

Data analysis and report writing were completed by Alanna Sutton, Brock Epp and James Ehnes. Cartography was completed by Alex Snitowski.

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1.0 INTRODUCTION

1.1 BACKGROUND

Construction of the Keeyask Generation Project (the Project), a 695 megawatt hydroelectric generating station (GS) and associated facilities, began in July 2014. The Project is located at Gull Rapids on the lower Nelson River in northern Manitoba where Gull Lake flows into Stephens Lake, 35 km upstream of the existing Kettle GS.

The *Keeyask Generation Project Response to EIS Guidelines* (the EIS; KHLP 2012a), completed in June 2012, provides a summary of predicted effects and planned mitigation for the Project. Technical supporting information for the terrestrial environment, including a description of the environmental setting, effects and mitigation, and a summary of proposed monitoring and follow-up programs is provided in the *Keeyask Generation Project Environmental Impact Statement Terrestrial Supporting Volume* (TE SV; KHLP 2012b). The *Keeyask Generation Project Terrestrial Effects Monitoring Plan* (TEMP; KHLP 2015) was developed as part of the licensing process for the Project. Monitoring activities for various components of the terrestrial environment were described during the construction and operation phases.

High accumulations of road dust on vegetation were incidentally observed at one site near the North Access Road (NAR) bridge while conducting the 2016 terrestrial habitat monitoring. The dust accumulations in this location extended more than 100 metres from the road, which was well beyond the distance predicted in the EIS.

Several studies have found that road dust accumulations can have adverse effects on vegetation and soils. Based on this information, it is possible that actual Project effects on terrestrial habitat and ecosystems may be higher than predicted in the EIS, depending on how much area is affected by high accumulations of road dust.

In 2018, a new monitoring study was initiated under the TEMP to document the approximate spatial extent of road dust accumulations on vegetation, and to evaluate the degree to which this unanticipated impact could alter EIS conclusions regarding Project effects on terrestrial habitat and ecosystems.

A previous report (ECOSTEM 2019) provides results for the 2018 road dust on vegetation studies. This report presents the results from the monitoring data collected in 2020.

1.2 OBJECTIVES

The objectives of the Road Dust on Vegetation study are to:

- Document approximately how far road dust accumulations on vegetation extend from the Project access roads; and,
- Evaluate the degree to which road dust accumulations on vegetation could alter EIS conclusions regarding Project effects on terrestrial habitat and ecosystems.

1.3 LITERATURE OVERVIEW

Few studies have been conducted on the effects of road dust on vegetation or soils, and even fewer are based on data from ecosystems that are directly comparable to those found in the Keeyask region. Most of the studies that have examined the effects of road and/or industrial dust focused on very different ecosystem types (Matsuki *et al.* 2016; Supe and Gawande 2015), and/or were in industrialized areas. The studies that looked at the effect of dust on the growth and function of specific plant species (Farmer 1993; Wijayratne *et al.* 2009; Zia-khan *et al.* 2015) did not include any of the species found within the Keeyask region. Literature reviews regarding the effects of road dust on vegetation and soils are provided by Farmer (1993) and Spellerberg and Morrison (1998).

The most comprehensive studies on the effects of road dust took place in the Alaskan tundra (Auerbach *et al.* 1997; Myers-Smith *et al.* 2006; Walker and Everett 1987). Coincidentally, of all the relevant studies, these ones were conducted in a region whose ecological conditions are most comparable to Keeyask region conditions (albeit not a close match).

Table 1-1 summarizes literature findings relevant for the types of vegetation and soils found in the Keeyask region. The Alaskan studies (Auerbach *et al.* 1997; Myers-Smith *et al.* 2006; Walker and Everett 1987) documented the cumulative effects of dust deposition on vegetation and soils in the same area along an unpaved highway over approximately 25 years. For vegetation, these studies found that increasing dust accumulation was associated with a decrease in plant biomass, and/or a change in vegetation composition. As dust accumulations increased, sphagnum mosses, feather mosses and lichens were the first species groups to be affected, followed by conifers and ericaceous shrubs (Auerbach *et al.* 1997; Myers-Smith *et al.* 2006; Walker and Everett 1987). Myers-Smith *et al.* (2006) found that moss, evergreen shrub, lichen and forb cover declined while cloudberry (*Rubus chamaemorous* L.) and graminoid biomass increased with proximity to the road over the long-term (~25 years).

For soils, the Alaskan studies found that effects included an increase in the alkalinity of the fibric soil horizon, lower nutrient levels, and a change in organic horizon thickness (Auerbach *et al.* 1997; Myers-Smith *et al.* 2006). Fibric horizon pH continued to rise over the long-term (~25 years; Myers-Smith *et al.* 2006).

Studies in the hardwood forests of the northeastern US (Brown 2009; Neher *et al.* 2013) found that road dust accumulation or proximity to roads increased the presence of some invasive species and altered roadside soil chemistry. Brown (2009) and Neher *et al.* (2013) found that soil pH increased with proximity to a road.

Literature reviews regarding the effects of road dust on adjacent vegetation communities (Farmer 1993; Spellerberg and Morrison 1998) concluded that northern arctic ecosystems, particularly bryoid and lichen dominated vegetation communities, were particularly sensitive to dust accumulation. Farmer (1993) noted that trees, shrubs and sedges appeared to be more tolerant to dust, compared to sphagnum and feather mosses, and lichens (particularly epiphytic lichens). Neher *et al.* (2013) observed that the effects of road dust did not extend beyond the forest edge in their study, presumably due to a vegetation barrier effect.

Table 1-1: Findings relevant for Keeyask region ecosystems from the literature

Source	Habitat	Findings Relevant for Keeyask Ecosystems
Walker & Everett 1987	Alaskan taiga and tundra	Effects of dust: Early snowmelt (lower albedo), decrease in sphagnum mosses (increase in minerotrophic mosses) and lichens. Few effects on vascular plant abundance, except for ericaceous shrubs and conifers where dust accumulation is very high.
Auerbach *et al.* 1997	Alaska tundra	Effect of gravel road dust over 15 years: Soils were more basic due to calcareous road dust, lower nutrient levels, lower moisture, altered OM depth. Vegetation biomass reduced nearer the road. Veg composition altered most in acidic tundra, sphagnum mosses nearly eliminated nearer road.
Myers-Smith *et al.* 2006	Alaska tundra	Effect of road dust over 25 years (update to Auerbach *et al.* 1997): Fibric horizon pH continued to rise, community adjacent to road higher *Rubus chamaemorous* and graminoid biomass, lower moss, evergreen shrub, lichen and forb biomass.
Brown 2009	Pennsylvania hardwood forest	Effect of road dust on forest organic soils and vegetation: Road dust altered roadside soil chemistry, especially limestone dust (increased pH), possibly aiding establishment of invasive species.
Neher *et al.* 2013	Vermont hardwood forest	Effect of road dust: Cleared area determined distance road pollutants travelled. Increased alkalinity with proximity to roads. Effects did not extend beyond forest edge, presumably due to vegetation barrier.
Farmer 1993[1]	Variety	Of the ecosystems studied, the most sensitive to dust were bryophyte-dominated plant communities (e.g. sphagnum) of the north. Trees, shrubs and sedges more tolerant, sphagnum, feather mosses and lichens (especially epiphytes) least tolerant.
Spellerberg, Morrison 1998[1]	Variety, New Zealand	Cited sensitivity of arctic bryophyte and lichen communities (Farmer 1993).

[1] Literature review.

In general, small degrees of natural leaf mortality are expected to be widespread. Individual leaf mortality has been found to occur more frequently during the growing season than over winter for several tundra species (Chapin et al. 1975, Shaver 1981, 1983). It is believed that this occurs primarily due to nutrient resorption, particularly in nutrient poor conditions (Chapin 1980), although nutrient resorption may be important regardless of nutrient availability and growth form (Aerts 1996).

2.0 METHODS

2.1 OVERVIEW

This is a reconnaissance level study (i.e., covers a wide range of conditions with limited detail) given the limited amount of scientific literature from comparable ecological conditions, the total length of the main access roads, the wide variety of vegetation and soil conditions along the roads, and the uncertainty as to the extent and degree of dust accumulation.

This study was carried out in two stages as virtually no existing information was available regarding road dust accumulation on vegetation in the vicinity of the Project access roads. Additionally, very little relevant information was available for the length of time it would take to collect data at each sample location.

Stage 1 of the data collection, which was conducted in 2018, was focused on obtaining: data to suggest how frequently road dust was accumulating on vegetation at distances of 100 m or further (i.e., beyond the cautiously assumed distance used for the EIS); and, information needed to establish a sampling protocol for subsequent sampling. Stage 2 of the data collection was conducted in 2020 using refined field methods that reflected what had been learned from Stage 1.

2.2 INFLUENTIAL FACTORS

Key factors that could potentially influence either road dust accumulation on vegetation or plant responses to dust were identified from the relevant literature (Section 1.3). The key factors for vegetation along the access roads included:

- Proximity of the sample site to the road:
  - Dust will settle out of the air. In the absence of wind, dust settlement will lead to decreasing accumulations with distance from the road;
- Vegetation structure, including the area of cleared vegetation, between the road and the sample site:
  - It was expected that tall vegetation will tend to intercept dust that is being transported away from the road;
- Vegetation height and density at the sample site:
  - Increasing values for either of these attributes was expected to intercept more dust, which would increasingly limit how far it spreads from the road;
- Amount of recent rainfall:

    - Rainfall could have two counteracting effects. While rain may partially wash deposited dust from leaves resulting is less accumulation, the wet leaf surfaces may adhere dust better resulting in higher accumulation;
- Dust chemistry:
    - Plant health is affected by dust chemistry (e.g., pH, presence of toxic elements);
- Plant type:
    - Some species are more sensitive to dust than others;
    - Some species vary in their capacity to trap dust; and,
- Trends in the local prevailing wind direction:
    - Dust cover may be more extensive in the downwind direction.

2.3 PRE-EXISTING DATA

There were no pre-existing data available for this study. Incidental observations from 2016 identified one site with high accumulations of road dust more than 100 m from the road. This site was located off the North Access Road, near Looking-Back Creek.

2.4 DATA COLLECTION: STAGE 1

2.4.1 OVERVIEW

Two approaches were used to collect relevant information in 2018, which was when data were first collected for this study.

On July 2, 2018 possible data collection methods were tested and observations on the distances from the access roads with dust accumulations were made at 10 sites. These dust searches occurred at road locations with visible high dust accumulations. The surveyor walked in a straight line oriented perpendicular from the road (i.e., the edge of the roadbed) until it was obvious that the maximum distance of dust accumulation had been reached.

Additionally, over the subsequent seven days, staff occasionally stopped along the North Access Road while conducting other plant monitoring to take photos of the dust accumulation and record how far dust accumulations were present away from the road.

Information from the July fieldwork was used to develop the sampling design and methods employed in August, 2018.

A key challenge that arose during both stages of this study was coordinating the timing of the data collection to minimize the effects of recent rains on dust accumulation.

2.4.2 SAMPLE LOCATIONS

Bands of vegetation extending at least 400 m from the road were selected as potential sample locations. Two criteria were used to select the vegetation bands that would become potential sample locations. First, the bands were in the road segments that had a relatively high level of construction traffic. Second, they had relatively homogenous vegetation height and density extending between 100 m and 400 m perpendicular from the north or south access roads. This criterion was to control for the potential confounding effect that variability in vegetation structure (e.g., forest versus low vegetation) between the road and the sample site could have on dust accumulations.

Vegetation bands meeting the two selection criteria were identified from the terrestrial habitat mapping, 2013 burn mapping and high-resolution digital orthoimages (DOIs). It was recognized that there may be small patches within these bands that had a different vegetation structure than the overall band due to localized variability in soils and/or topography.

One straight-line transect, oriented perpendicular to the road, was established in the center of each of the selected vegetation bands (Map 2-1). The total transect length that was sampled depended on the observed dust accumulations (see below). Waypoints for the transect start and end points were recorded from a handheld GPS.

Sample sites were positioned systematically along each straight-line transect. The first sample site was located 100 m from the road (the assumed typical maximum distance for Project effects). Subsequent sample sites were spaced 25 m apart until the maximum distance was reached. The maximum distance occurred once three sample sites in a row had no visible dust accumulation on foliage.

Eight transects were sampled along the North Access Road (NAR) and four along the South Access Road (SAR). Map 2-1 shows the locations of the potential vegetation bands as well as the subset that was sampled on August 19 to 21, 2018.

2.4.3 DATA COLLECTED

At each sample site, data were collected in a 1 m diameter (0.785 m^2) cylindrical quadrat that was vertically subdivided into four height strata (i.e., tall, moderate, short and ground; see Table 2-1 for definitions).

Table 2-1: Height strata

Code	Stratum	Description
T	Tall	The volume within the cylindrical quadrat that is between the heights of 81 cm and 150 cm. Typically includes tall shrubs and lower branches of trees.
M	Moderate	The volume within the cylindrical quadrat that is between the heights of 41 cm and 80 cm. Typically includes low shrubs, foliage of tall herbs and lower foliage of tall shrubs.
S	Short	The volume within the cylindrical quadrat that is between the heights of 6 cm and 40 cm. Typically includes herbs, lower foliage of low shrubs.
G	Ground	The volume within the cylindrical quadrat that is below 5 cm in height. Includes ground mosses and lichens, foliage of prostrate herbs or woody species (e.g., *Vaccinium oxycoccos* L., *Linnea borealis* L.).

The cylindrical quadrat used for data recording (see below) was centered on the transect at the sample distance. If a quadrat at the required distance had more than one mapping-level habitat type within 10 m of the point, the quadrat center was moved perpendicularly to the transect into the closest homogenous habitat patch.

A permanent stake and flagging tape were left at the center of each sampled quadrat. A waypoint was recorded for the quadrat location with a handheld GPS.

A 1 m diameter, circular hoop made from flexible HDPE pipe was used to delineate the perimeter of the cylindrical quadrat. The circular hoop was placed on the ground to sample the ground stratum, and at the lowest height of each of the remaining strata.

2.4.3.1 Entire Cylindrical Quadrat

Table 2-2 provides the attributes recorded for the entire cylindrical quadrat.

Vegetation structure (Table 2-3) identified the tallest vegetation layer that had at least 25% leaf cover (i.e., the tallest vegetation structure class took precedence over the lower classes). For this reason, a forest or woodland could still have a tall shrub and/ or low shrub understorey. The overall vegetation structure of a transect was based on the dominant structure types of the sites sampled along it.

Table 2-2: Attributes recorded for the entire cylindrical quadrat

Attribute	Definition
Transect	Transect ID, which is a combination of the Protocol (D); Study Area (N=North Access Road; S=South Access Road); and Location Number (Number of the transect starting at 01 for each of the two roads and then incrementing by one).
Date and Time	The month, day and time (24h format) of sampling.
Distance	Distance of plot from roadbed edge in 25 m increments.
Coordinates	The UTM Easting and Northing at the plot origin.
Vegetation Structure*	See Table 2-3.
Tree Cover*	Percent cover for tree foliage if present.
Dominant Tree Species*	Tree species (>1.3 m tall) in descending order of abundance.
Recent Burn*	Identifies if the plot burned in the past 10 years. Y=yes, N=no and P= partially burned.
Percent Bare Ground*	Percentage of the quadrat that has bare ground (non-living ground cover).
Total Organic Material Thickness*	Total thickness of surface organic material, including LFH.
LFH Thickness*	Total thickness of the LFH layer.

Note: * Denotes attribute was recorded within the cylindrical quadrat during Stage 1 only.

Trees taller than 1.3 m that were present in the quadrat were recorded in descending order of abundance. The total percentage of understorey leaf cover and bare ground were recorded. Bare ground included any non-living cover in the ground stratum (e.g., mineral soil, litter, water). The average thickness of the surface organic layer in the quadrat was also recorded using a survey pin. The surface organic layer included any litter (LFH) layer and organic soil layers on top of mineral material. If the depth of the surface organic layer was thicker than the length of the survey pin, a depth “>30 cm” was recorded.

Table 2-3: Vegetation Structure Classes

Type	Class	Definition
Treed (T)	Forest	Trees (i.e., tree species with stems that have Diameter at Breast Height (DBH) > 0) formed the canopy and those trees have >=75% canopy closure. Only trees were included in the canopy closure estimate; shrubs not included in estimate.
	Woodland	Trees (i.e., tree species with stems that have DBH > 0) formed the canopy and those trees had =>25% and < 75% canopy closure. Only trees were included in the canopy closure estimate; shrubs not included in estimate.
Tall Shrub (S)	Shrubland- Tall	Tall shrubs (shrub species whose height >= 0.5 m) and/ or saplings (tree species >0.5 m < DBH) formed the canopy and had at least 25% cover.
Low (L)	Shrubland-Low	Low shrubs (shrub species whose height < 0.5 m) or tree seedlings (tree species < 0.5 m tall) formed the canopy and had at least 25% cover.
	Grassland/ Herbland	Grasses and/ or sedges and/ or herbs formed the canopy and had at least 25% cover.
	Bryoid	Mosses, hepatics and/ or lichens were the tallest vegetation with at least 25% cover.
	Sparse	All vegetation combined has >= 25% cover if all of the strata were combined but no one stratum had at least 25% cover.
	Barren	All vegetation combined had < 25% cover.

2.4.3.2 STRATUM

Additional data were collected separately for each of the height strata (Table 2-1) within the vertically subdivided cylindrical quadrat. Therefore, each sample site had up to four measurements for each stratum attribute (i.e., one for each stratum). Table 2-4 provides the attributes recorded for each of the stratum quadrats.

Dust accumulation on leaves was recorded using three variables, including the percentage of foliage covered by dust, the average thickness of dust cover, and the variability of dust thickness (see Table 2-4 for definitions).

Table 2-4: Attributes recorded for each 1m Diameter Stratum Quadrat

Attribute	Definition
Dust Coverage	Percentage of the leaf cover in the stratum with dust on it.
Dust Thickness	Average dust thickness on leaves with dust using the classes in Table 2-5.
Dust Variability	How variable the dust thickness is on leaves with dust using the classes in Table 2-6.
Vegetation Cover	Percentage cover of all foliage in the stratum.
Plants	Every species meeting the minimum percent cover (25% for all species except for narrow-leaved ones, which is 10%) in the quadrat area.
Leaf Mortality	Estimate of the percent of leaf cover that is dead for each of the recorded species.

Total leaf cover for all species was estimated as the percentage of the circular quadrat area. Plant species covering 25% or more of the quadrat area in a stratum, or 10% or more for narrow-leaved species such as grasses, were recorded in descending order of abundance. Tree growth forms were recorded separately as pseudo-species, including tree (>1.3m tall), sapling (0.5-1.3m tall), or seedling (<0.5 m tall). Broader taxonomic groups were used for species that would be difficult to identify quickly (e.g., *Cladonia* spp, *Sphagnum* spp, *Peltigera* spp). Additionally, species mixtures were recorded when more than one species of the same type grew intermingled together to the degree that it made estimating the 25% minimum cover very time consuming (this was usually employed for moss species or mixtures of tree pseudo-species).

Percent leaf mortality was estimated for each of the recorded species based on a visual estimate of the percent of dead leaf tissue in the total leaf cover of the species in the stratum.

Any rare or non-native plant species present in the quadrat, or incidentally observed while moving between sample sites, were recorded.

Table 2-5: Dust Thickness Classes

Class	Definition
None	No diminution of the natural leaf cover by road dust. Occurs if there is no dust in addition to what would be there from natural airborne dust deposition.
Thin	Slight opaqueness to the natural leaf cover.
Moderate	Moderate opaqueness to the natural leaf cover OR Leaf not visible in less than 25% of the leaf area and mildly obscured in most of the rest of the area.
Thick	High opaqueness to the natural leaf cover OR Leaf not visible in between 25% and 75% of the leaf area.
Very Thick	Leaf surface not visible through the dust.

Table 2-6: Dust Thickness Variability Classes

Class	Definition
None	Dust thickness is highly similar throughout the stratum.
Low	Dust thickness varies to a low degree throughout the stratum.
Moderate	Dust thickness varies to a moderate degree throughout the stratum.
High	Dust thickness is highly variable throughout the stratum.

2.4.4 SITES SAMPLED

A small number of transects (12) were sampled in 2018 because one of the purposes of the Stage 1 fieldwork was to test the effectiveness and efficiency of possible sampling methods and determine appropriate methods for Stage 2.

Sampling for all attributes except for dust coverage, thickness and variability occurred on every sample day. Dust accumulation data were only collected when there had been less than 5 mm of total rainfall over the preceding seven days since visible dust accumulations on shrub and herb foliage are influenced by the amount of recent rainfall. Daily precipitation data were obtained from two weather stations: a Manitoba Hydro station on the north arm of Stephens Lake; and a NAVCAN station at the Gillam airport. While the Stephens Lake data were more spatially relevant, the quality of these data were unknown. A review of the weather data found some large differences in the daily amounts of precipitation recorded at the two stations. However, these differences could be due to localized variations in weather given that the stations were approximately 36 km apart.

During the preliminary fieldwork in early July 2018, 10 locations along the NAR were surveyed for dust accumulations. Dust was not observed on foliage further than approximately 80 m from the roadbed during these searches.

Data were collected at 47 sites along transects at 12 locations along the NAR and SAR in August 2018. Eight transects were located along the NAR and four transects were along the SAR.

2.4.5 ANALYSIS

The analysis of the 2018 data was limited to descriptive statistics. As planned, too few replicates (i.e., 12 transects) had been sampled to evaluate associations between dust accumulations and factors such as vegetation structure, traffic volume, topography, prevailing wind direction, or to determine if dust is adversely affecting the vegetation. Limited replication was implemented in 2018 because one of the purposes of the 2018 fieldwork was to test the effectiveness and efficiency of possible sampling methods.

2.5 DATA COLLECTION: STAGE 2

2.5.1 BACKGROUND

The key findings from Stage 1 of this study (carried out in 2018) guided the Stage 2 design refinements. The primary focus of these refinements was on maximizing the data available to document the spatial extent of road dust effects. Secondary considerations included collecting some data to evaluate the factors that affect the distance that the dust travels and how the dust has affected vegetation. The key Stage 1 findings that guided the Stage 2 design refinements were as follows.

The 2018 results found that road dust was infrequently accumulating on vegetation 100 m or further from the access roads (i.e., five of the 12 sample locations). All of these locations were along the NAR. Additionally, only three of the 12 locations had dust on leaves more than 100 m from the road.

The absence of dust accumulations at locations along the SAR was not surprising given that the traffic volume on the SAR was considerably less than on the NAR (e.g., 39 versus 90 vehicles per day between April 2019 and March 2020; Manitoba Hydro 2020). However, it was also possible that other factors such as terrain and generally denser vegetation along the sampled transects were at least partially contributing to the differing pattern along the two access roads.

The maximum recorded distance for dust accumulation in 2018 was 150 m. At both transects where this was observed, the sample locations predominantly had low vegetation. While this apparent association between vegetation structure and dust accumulation was consistent with the literature, it could also be the result of other factors such as topography, traffic volume, road material and prevailing winds.

No attempt was made to statistically explore the factors that were potentially responsible for variations in degree and spatial distribution of dust accumulation given there were only 12 replicates.

The other important consideration for the Stage 2 design refinements was that this study was intended to be conducted at a reconnaissance level. This approach was due to the lack of pre-existing relevant information and the uncertainty as to the degree and extent of dust accumulation beyond 100 m from the access roads.

2.5.2 APPROACH

The following details the method refinements used during the Stage 2 sampling in 2020.

During sampling in August, it became evident that dust accumulation data could not be documented in 2020 due to frequent rainfall. The seven-day accumulation of less than 5 mm of

total rainfall was only met on 11 of the days between June 20 and the second week of September in 2020. Total rainfall in the past seven days was as follows for each sample day:

- July 23 to 27 field tour:
  - In the week preceding fieldwork, there had been minimal rainfall, and as such July 23 met the rainfall criteria, however, 28.3 mm fell on July 24, which precluded collecting dust accumulation data for the remainder of the field tour.
- August 14 to 17 field tour:
  - This field tour followed a week of rainfall between 3 and 7 mm per day. The rainfall criterion was not met until the final day of the fieldwork (August 17) and only lasted until the 19th.

As a result, dust accumulation data were not collected along any of the transects. In place of using dust accumulation to determine transect length, the new locations for 2020 were sampled up to the minimum transect length, which was 150 m from the roadbed (Section 2.4.2). The 2018 sites that were re-sampled were sampled to the same transect length as was sampled in 2018.

The lack of dust accumulation data for 2020 was not considered to be a serious limitation to this study. If road dust had adversely affected vegetation, then the expectation was that, on average, leaf mortality and damage would exhibit a decreasing trend with distance from the access road. To strengthen the ability to detect such a pattern, a 50 m sample site was added to all the transects in August. The 50 m distance had the highest likelihood of having road dust effects. To increase replication for the 50 m site, the August data collection also included a new sample site at this distance on the transects sampled in July.

Another substantive refinement to the 2020 data collection was the addition of a 10 m square context plot at each sample site. This plot was added to better describe the conditions surrounding the site.

Additional plant health attributes were collected in 2020, including leaf damage and the damage agent if it could be determined. These attributes were added since dust effects may weaken a plant's ability to cope with secondary stresses such as drought and insects (Farmer 1993).

2.5.3 Sample Locations

Locations were not sampled along the SAR in 2020 (Map 2-1) given that the SAR locations did not have dust accumulations in 2018, and a reconnaissance level study includes a relatively low number of replicates.

All of the sites sampled in 2018 were resampled in 2020 to provide consistent data for both sample years.

2.5.4 DATA COLLECTED

This section details the differences in the data collected in Stage 2 (2020) compared with Stage 1 (2018).

2.5.4.1 SQUARE PLOT

A 10 m square plot (centered on the quadrat) was added in 2020 at each sample site.

Table 2-7 provides the attributes recorded for the entire square plot. Several variables, including vegetation structure, as well as general tree and ground cover variables (see Table 2-7) were determined within the square plot in Stage 2, rather than the cylindrical quadrat.

Attributes recorded within the square plot which had not been recorded during Stage 1 included dominant ground cover species (in descending order of abundance), slope and aspect.

Table 2-7: Attributes and Definitions for variables recorded for the 10 m square plot, sampled during Stage 2

Attribute	Definition
Vegetation Structure	See Table 2-3.
Tree Cover	Percent cover for tree foliage if present.
Dominant Tree Species	Tree species (>1.3 m tall) in descending order of abundance.
Recent Burn	Identifies if the plot burned in the past 10 years. Y=yes, N=no and P= partially burned.
Percent Bare Ground	Percentage of the quadrat that has bare ground (non-living ground cover).
Total Organic Material Thickness	Total thickness of surface organic material, including LFH.
LFH Thickness	Total thickness of the LFH layer.
Dominant Ground Cover	Dominant ground cover by taxa in descending order of abundance
Aspect	The aspect of the circular plot
Slope	The slope of the circular plot

2.5.4.2 CYLINDRICAL QUADRAT DATA

The quadrat data collection methods for Stage 2 were the same as in Stage 1 with the following exception: variables describing the plot (Table 2-7) were sampled within the 10 m plot rather than the quadrat.

2.5.4.3 STRATUM DATA

The quadrat stratum data collection was expanded to include leaf damage, which was recorded for each of the species in each stratum. This was based on a visual estimate of the percent of damaged leaf tissue in the total leaf cover of the species in the stratum (Table 2-8). Damaged leaf

tissue was identified as having spots or blemishes, or damage from fungal infection or herbivory. Table 2-9 lists the leaf damage categories used.

Table 2-8: Attributes added to each 1m diameter stratum quadrat for Stage 2

Attribute	Definition
Leaf Damage	Estimate of the percent leaf appearing unhealthy for each of the recorded species
Leaf Damage Type	Type of damage appearing on unhealthy leaves using the classes in Table 2-9.

Table 2-9: Foliage damage type categories

Class	Definition
Discolouration (D)	Leaves displaying discolouration
Fungal (F)	Leaves displaying fungal infection damage
Herbivory (H)	Leaves displaying herbivory damage

2.5.5 SITES SAMPLED

Data were collected along 22 transects along the NAR over two periods in 2020: July 23 to 27, and August 14 to 17. A total of 99 sites were sampled on these transects, including resampling the 35 sites on the eight NAR transects that were sampled in Stage 1. In total, 325 stratum quadrats were sampled within the 99 sites. No transects were sampled along the SAR.

At least four sample sites, starting at 50 m from the road (Section 2.5), were sampled along each transect established in 2020. In transects that were established in 2018 and resampled in 2020, up to seven sample sites were sampled. The greater distance compared with the 2020 transects reflected the maximum distances sampled in 2018 and the addition of a site at 50 m.

Map 2-1 shows the locations of the vegetation bands sampled in 2020.

2.5.6 ANALYSIS

In order to determine if there was a possible link between dust accumulation and plant health, leaf heath data was analyzed relative to distance from the road. It was assumed that, on average, dust accumulation on vegetation would decrease with increasing distance from the road. If the data indicated that sites closer to the roadbed had significantly higher leaf mortality or damage, it would suggest road dust accumulation as a possible cause.

The leaf mortality and damage results used to evaluate potential adverse road dust effects include:

- Overall occurrence;
- Site-level vegetation structure type;
- Seasonality (July versus August);

- Strata within sites;
- Distance from road (i.e., edge of the roadbed), including the number of affected species, and individual species effects.

The leaf health data collected in the strata occurring in each quadrat was generalized to the site-level using the stratum with the maximum recorded adverse value.

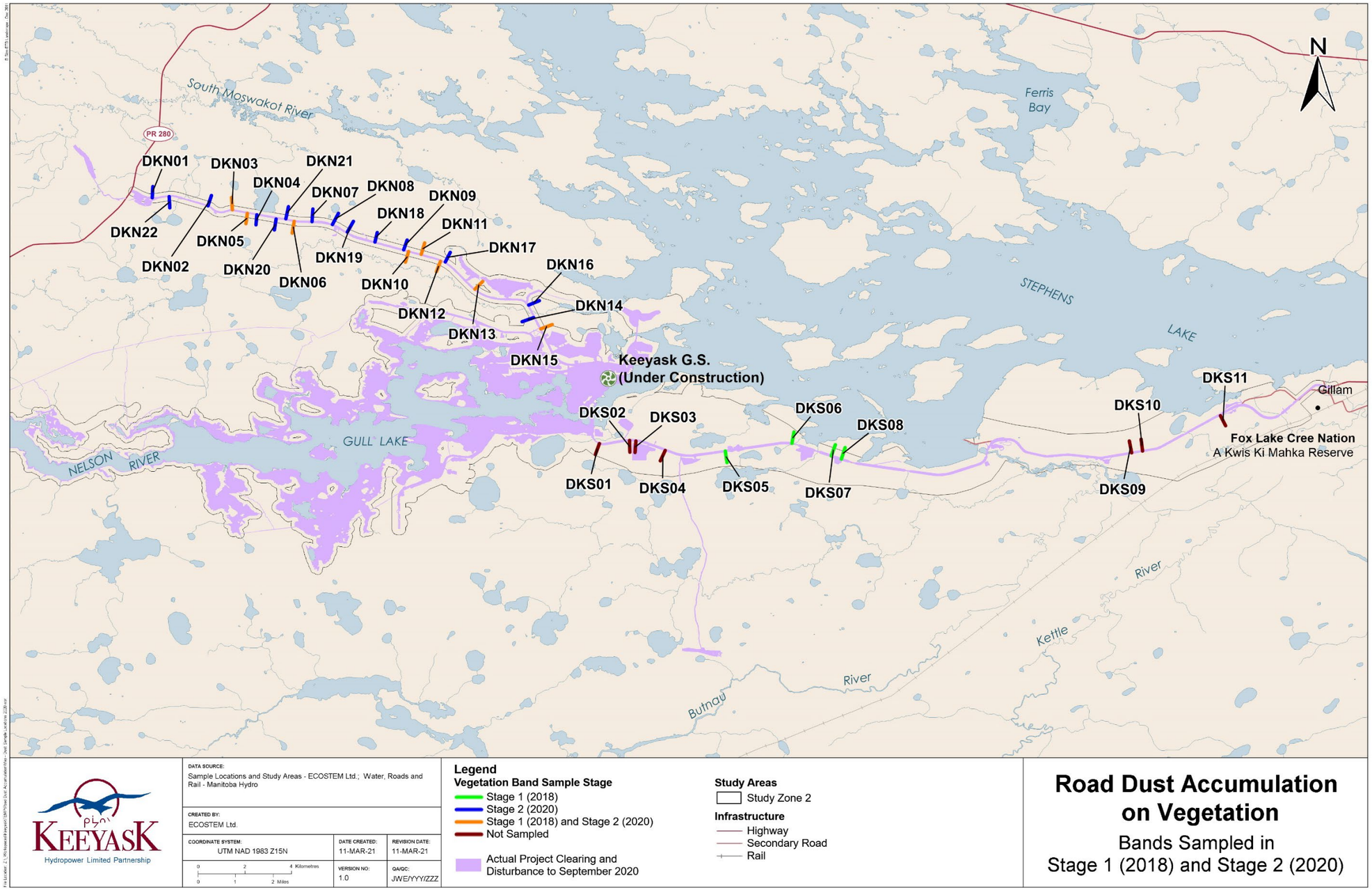
For comparisons of leaf damage between different distances from the road and identifying potential trends related to road dust accumulation, only discoloration and fungal damage was considered. It was anticipated that the degree of insect herbivory would not materially change with dust accumulation, and inclusion of that damage type might mask possible distance effects associated with the other types.

Plants recorded as broader taxonomic groups which represent more than one species (see Section 2.4.3.2), were excluded from the analysis because it is possible that different species in the group may respond differently to dust accumulation. Pseudo-species were combined into single species because the separation was based on plant size, and their growth form was not expected to influence their response to dust accumulation. Additionally, species occurring in fewer than 10 sites were excluded from the analysis because the low sample numbers make trends difficult to distinguish from natural variability.

Comparisons of leaf mortality and damage for individual species at different distances from the roadbed were limited to the pooled July and August data, excluding the 50 m, 175 m, 200 m, and 225 m sites. When the August transects were isolated, only one species was present in more than 10 sites. When species were subdivided into the separate sites the number of occurrences was too low to infer trends or make meaningful comparisons. Additionally, there were too few sites sampled at greater than 150m to compare individual species at those distances.

Statistical comparison of means was made using a one-way analysis of variance (ANOVA) in SPSS.

Possible associations between vegetation effects and levels of dust accumulation were not statistically tested as replication was too low.



Map 2-1: Vegetation bands sampled in Stage 1 (2018) and Stage 2 (2020)

3.0 RESULTS

3.1 VEGETATION STRUCTURE

Figure 3-1 shows the vegetation structure of each of the 99 sites sampled along transects at the 22 road locations. The overall vegetation structure of the 22 transects included four with low vegetation, five with mixed low and tall shrub vegetation, six with tall shrub vegetation, two with a mixed tall shrub and treed vegetation and five with treed vegetation. Six transects (i.e., DKN01, DKN05, DKN09, DKN14, DKN18, DKN22) had the same vegetation structure in every plot along the transect (Table 3-1).

A majority of the transects (77%) and sample sites (73%) had either a low (i.e., herbaceous, bryoid or low shrub) or tall shrub vegetation structure type (Table 3-1). This was because wildfires had burned much of the area along the NAR in 1999 and/or 2001, and then again in 2013.

Table 3-1: Distribution of vegetation structure along the 22 sample transects based on number of sites

Transect[2]	Overall Vegetation Structure Type	Vegetation Structure Type[1]			Total Number of Sites
		Low	Tall Shrub	Treed	
DKN01	Low	4			4
DKN02	Low/tall shrub	2	2		4
DKN03*	Tall shrub	1	4		5
DKN04	Treed		1	3	4
DKN05*	Treed			5	5
DKN06*	Tall shrub/treed		4	3	7
DKN07	Low/tall shrub	2	2		4
DKN08	Tall shrub		3	1	4
DKN09	Low	4			4
DKN10*	Low/tall shrub	2	2		4
DKN11*	Mixture	2	3	1	6
DKN12*	Treed		1	4	5
DKN13*	Tall shrub		5	2	7
DKN14	Tall shrub		4		4
DKN15*	Treed		1	3	4
DKN16	Low	3	1		4
DKN17	Tall shrub		3	1	4
DKN18	Tall shrub		4		4
DKN19	Tall shrub		3	1	4
DKN20	Treed		1	3	4
DKN21	Low/tall shrub	2	2		4
DKN22	Low	4			4
All 22 Transects		26	46	27	99

Notes: [1] "Low" structure includes the Shrubland- Low, Grassland/ Herbland, Bryoid, Sparse and Barren vegetation structure classes; and "Treed" includes the Forest and Woodland classes (see Table 2-3). [2] "*" denotes transect first sampled in 2018

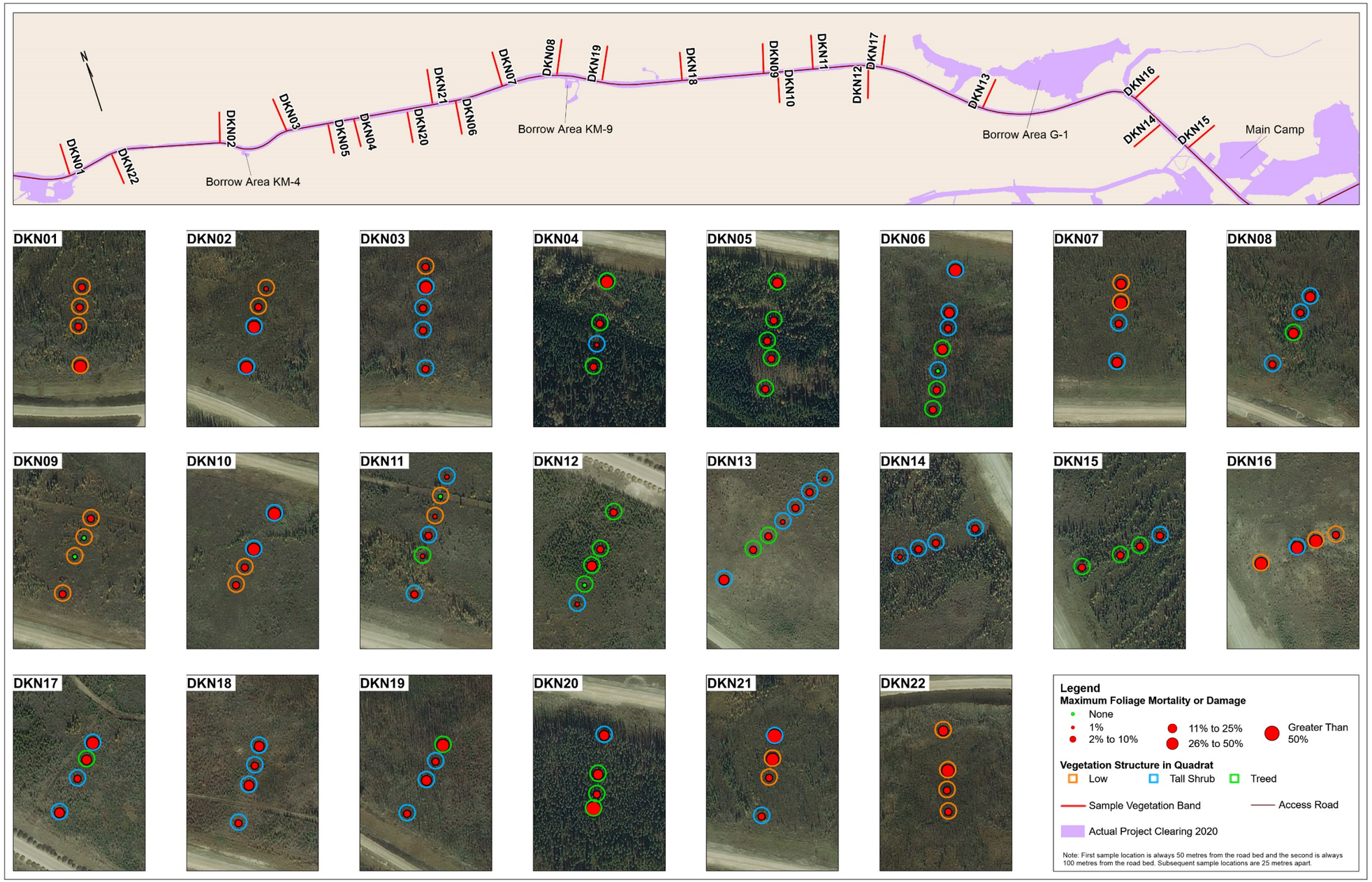


Figure 3-1: Leaf damage or mortality in sites sampled on transects along the North Access Road

3.2 LEAF DAMAGE AND MORTALITY

3.2.1 OVERALL OCCURRENCE

Leaf mortality and/or leaf damage was recorded in 94 (95%) of the 99 sample sites in 2020 (Table 3-2). Leaf mortality was recorded in 42% of the sample sites, and leaf damage was recorded in 94 (95%) of the sample sites. The most common type of leaf damage was leaf discoloration (Photo 3-1), which was recorded alone or in combination with other damage in 89 (95%) of the sites with leaf damage (Table 3-3).

In a given site, leaf mortality varied by species and the stratum. Leaf mortality ranged from 1% to 50% of the leaf cover (Appendix 1: Table 6-1), and leaf damage ranged from 1% to 90% (Appendix 1: Table 6-2).

Table 3-2: Number and percentage of sampled sites with leaf damage or mortality

Leaf Health	Number of Sites	Percent of Sites[1]
Leaf damage or substantive mortality	94	94.9
Leaf damage	94	94.9
Substantive leaf mortality	42	42.4
Total sites	99	

Notes: [1] Percentages do not add to 100 because sites can have more than one health category.

Photo 3-1: Example of leaf discolouration and mortality on prickly rose along transect DKN16 in 2020

Table 3-3: Leaf damage type in sites where leaf damage was present

Leaf Damage Type	Number of Sites	Percent of Sites[1]
Discolouration	89	94.7
Fungus	26	27.7
Herbivory	43	45.7
Total number of sites with leaf damage	94	

Notes: [1] Sums of numbers and percentages in rows do not equal totals because sites may have more than one damage type.

A seasonal effect was apparent for leaf mortality and damage. Comparing sites sampled at the same distances from the road in both July and August, the percentage of sites with both leaf damage and mortality increased over the approximately 2.5 weeks between data collections (Table 3-4). The mean maximum percent of damaged leaf cover increased from 6.6% in July to

23.3% in August. This difference was statistically significant (α=5%; Table 3-5). The increase in mean leaf mortality from 1.3% to 3.4% over the same time period was not significant.

Table 3-4: Percent of sites and average percent of leaf cover with leaf damage and mortality comparing sites sampled[1] in July and August, 2020

Statistic	July	August
Number of sites	39	27
Percent of sites with leaf damage	92.3	100.0
Percent of sites with leaf mortality	5.1	37.0
Average percent of leaf cover with damage	6.6	23.3
Average percent of leaf cover with mortality	1.3	3.4

Notes: [1] Only the sites at distances sampled in both July and August are included for comparison.

Table 3-5: Analysis of variance of the mean maximum percent of leaf cover affected by mortality and damage for sites sampled[1] in July and August, 2020

Statistic	July	August
Leaf Damage		
N	39	27
Mean	6.56	23.33
Standard deviation	10.26	22.22
Significance[2]		**0.000**
Leaf Mortality		
N	39	27
Mean	1.26	3.41
Standard deviation	4.99	6.36
Significance[2]		0.129

Notes: [1] Only the sites at distances sampled in both July and August are included for comparison. [2] Bold values are significant at α=0.05.

The proportion of sites with leaf mortality and damage was similar across the site level vegetation structure types (Table 3-6). There was no statistically significant (α=5%) difference in the mean maximum percent of leaf mortality or damage between any of the site level vegetation structure types (Appendix 1: Table 6-3).

Table 3-6: Percent of sites with leaf mortality and damage by site level vegetation structure type

Site Structure Type	Number of Sites	Percent with Leaf Mortality	Percent with Leaf Damage
Low	26	38.5	88.5
Tall Shrub	46	47.8	97.8
Treed	27	37.0	96.3
All	99	42.4	94.9

3.2.2 STRATA

The ground and short strata were sampled in all 99 sites. The moderate height stratum was sampled in 76 sites and the tall stratum was sampled in 51 sites (Table 3-7).

Leaf mortality was most frequently recorded in the short stratum (i.e., the first stratum above the ground), occurring in 28% of the sites (Table 3-7). Mortality was least frequent in the tall stratum, present in only 6% of the sites where that stratum occurred.

Leaf damage was also most frequently recorded in the short stratum, present in 91% of the sites (Table 3-7). Leaf damage was least frequent in the ground stratum, present in 47% of the sites.

The proportion of sites with moderate and tall vegetation strata varied depending on the site structure type. In sites with low vegetation structure, the proportion of sites with moderate and tall strata were 50% and 12%, respectively (Table 3-8). In sites with treed vegetation structure, moderate and tall vegetation strata were present in 93% and 85% of the sites, respectively. Note that leaf cover in the tall strata may be absent in a site with a treed vegetation structure type because the site vegetation structure is based on a 10x10 m plot, while the strata are within a 1 m diameter cylindrical quadrat, and leaf cover in a site is usually heterogeneous.

The distribution of leaf mortality and damage in the different strata was similar across the different site structure types, with a couple exceptions: in the ground stratum, leaf mortality and damage was more frequent in sites with low vegetation structure, and less frequent in sites with treed vegetation structure (Table 3-9); while in the moderate stratum, leaf mortality was more frequent in the low vegetation structure type.

Table 3-7: Number of sites where each stratum was present and the percentage of sites with leaf mortality and damage present

Stratum	Number of Sites	Percent of Sites with Leaf mortality	Percent of Sites with Leaf Damage
Ground (<=5cm)	99	14.1	47.5
Short (>5 and <=40 cm)	99	28.3	90.9
Moderate (>40 and <=80cm)	76	11.8	78.9
Tall (>80cm and <=150cm)	51	5.9	82.4

Table 3-8: Strata present as a percentage of sites in each structure type

Stratum	Low	Tall Shrub	Tree
Ground (<=5cm)	100	100	100
Short (>5 and <=40 cm)	100	100	100
Moderate (>40 and <=80cm)	50	83	93
Tall (>80cm and <=150cm)	12	54	85
Total sites in structure type	26	46	27

Table 3-9: Percentage of sites with leaf mortality and damage by stratum and site structure type

Stratum	Statistic	Site Structure Type		
		Low	Tall Shrub	Treed
Ground (<=5cm)	Number of sites	*26*	*46*	*27*
	Percent of sites with mortality	19	17	4
	Percent of sites with damage	62	54	22
Short (>5 and <=40 cm)	Number of sites	*26*	*46*	*27*
	Percent of sites with mortality	12	35	33
	Percent of sites with damage	88	96	85
Moderate (>40 and <=80cm)	Number of sites	*13*	*38*	*25*
	Percent of sites with mortality	31	11	8
	Percent of sites with damage	62	89	72
Tall (>80cm and <=150cm)	Number of sites	*3*	*25*	*23*
	Percent of sites with mortality	0	4	9
	Percent of sites with damage	33	84	87

3.2.3 EFFECTS OF DISTANCE FROM ROAD

The seasonal difference in the occurrence of leaf mortality and damage introduced a partial confounding factor for within-transect comparisons between different distances from the road. This was due to the 50 m sites being subsequently added in August to the transects that were sampled in July (a refinement to address the complication introduced by frequent rain; see Section 2.5.1). Additionally, all transects with sites sampled at 175 m and greater were sampled in July only. For the transects sampled in July, differences between the 50 m sites and the other distances could be due to seasonal effects, rather than effects from dust accumulation. Consequently, comparisons of conditions in the 50 m sites only include the transects sampled in August.

Comparing all transects sampled in July and August, but excluding the 50 m sites, the average number of species with leaf damage and mortality was similar at all distances from the road (Table 3-10). Average percent of species with mortality was highest at the 100 m sites. The average percent of species with leaf damage was highest in the 125 m sites (Table 3-10). Statistical comparisons found no significant difference (α=5%) between sites at 100 m, 125 m and 150 m (Appendix 1: Table 6-4).

Table 3-10: Average number of species in sites from all transects by distance from roadbed with leaf mortality and damage[1]

Distance from Roadbed (m)[2]	Number of Sites	Average Number of Species	Average Percent of Species with Leaf Mortality		Average Percent of Species with Leaf Damage	
			Mean	Std. dev.	Mean	Std. dev.
100	22	5.8	16.1	17.0	38.5	22.7
125	22	5.0	18.0	25.1	48.8	25.6
150	22	5.0	6.7	11.3	45.0	30.5
175	6	5.2	0.0	0.0	25.8	37.4
200	3	6.0	0.0	0.0	17.5	20.5
225	2	5.0	0.0	0.0	31.3	26.5

Notes: [1] Leaf discolouration and/or fungus. [2] Distances greater than 150 m were sampled in July only, and are not comparable to other distances due to seasonal effects on leaf condition.

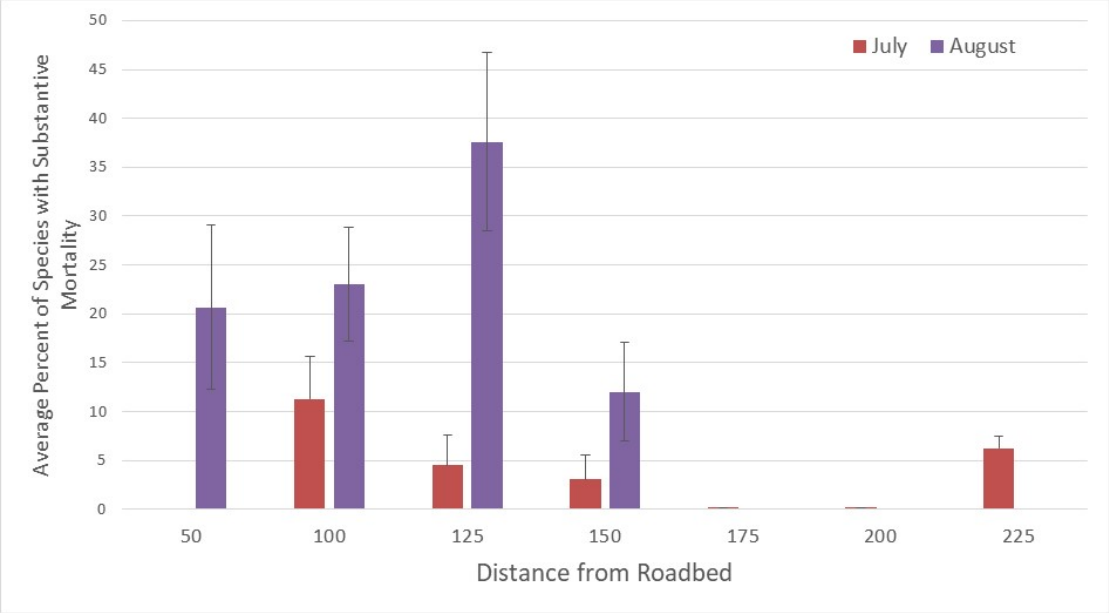
Considering only the transects sampled in August, and including the 50 m sites, the average number of species with mortality and leaf damage was highest at the 125 m sites and 150 m sites, respectively (Table 3-11). There was no significant difference between the 50 m sites and the other distances for both mortality and damage (Appendix 1: Table 6-5).

Table 3-11: Average number of species with leaf mortality and damage[1] in sites from August transects only by distance from roadbed

Distance from Roadbed (m)	Number of Sites	Average Number of Species	Average Percent of Species with Leaf Mortality		Average Percent of Species with Leaf Damage	
			Mean	Std. dev.	Mean	Std. dev.
50	9	5.1	20.7	25.1	65.2	10.3
100	9	4.2	23.0	17.4	56.2	12.3
125	9	3.7	37.6	27.3	72.4	13.8
150	9	3.9	12.0	15.1	74.1	18.4

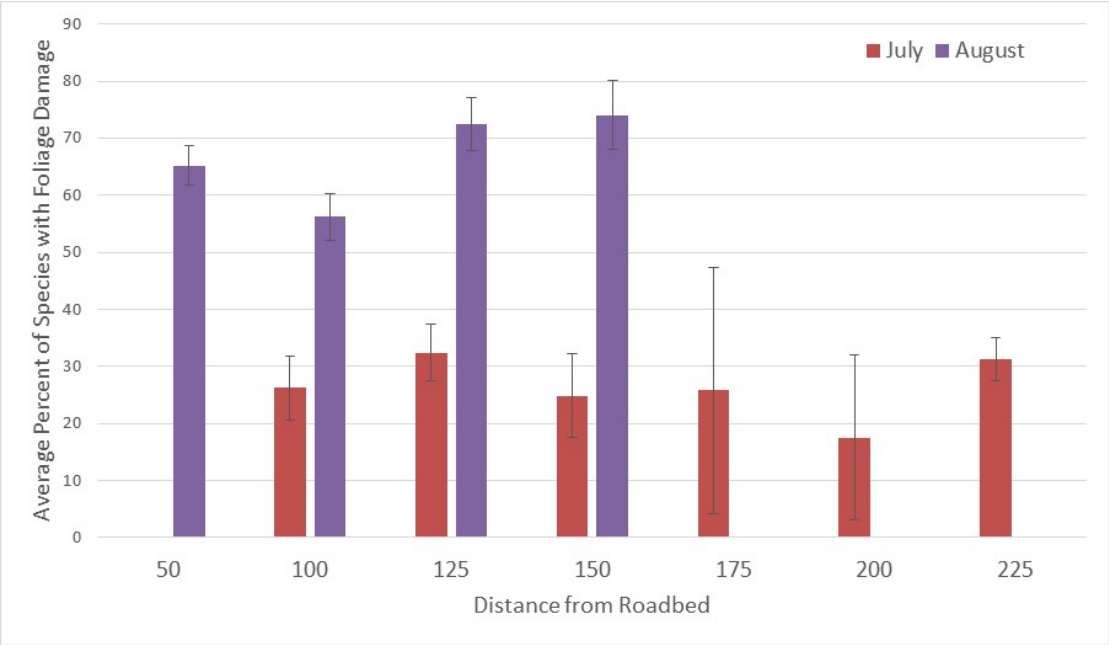
Notes: [1] Leaf discolouration and/or fungus.

Separate examinations of the July transects and August transects in isolation found no apparent increasing or decreasing trends in leaf mortality or damage with increasing distance from the road (Figure 3-2 and Figure 3-3).



Note: A thin bar with no error bar represents a value of "0". Absence of a bar indicates that no sites were sampled in that month.

Figure 3-2: Average number of species with substantive mortality at different distances from the roadbed for July and August transects. Error bars represent the standard error of the mean



Note: A thin bar with no error bar represents a value of "0". Absence of a bar indicates that no sites were sampled in that month.

Figure 3-3: Average number of species with leaf damage at different distances from the roadbed for July and August transects. Error bars represent the standard error of the mean

3.2.4 SPECIES

A total of 59 species and 12 groups identified to a higher taxonomic level (such as genus) with a minimum of 25% cover were identified in the 99 sampled sites in 2020 (Appendix 2: Table 6-6).

Fifteen species occurred in at least 10 sites (Table 3-12).

Table 3-12: Percentage of sites with substantive leaf mortality or damage for species with at least 25% cover present in at least 10 sample sites

Common Name	Scientific Name	Number of Sites where Present	Percent of Sites with Substantive Mortality	Percent of Sites with Leaf Damage
Labrador tea	*Rhododendron groenlandicum*	61	24.6	85.2
Fireweed	*Chamerion angustifolium*	19	15.8	78.9
Bog whortleberry	*Vaccinium uliginosum*	13	46.2	69.2
Myrtle-leaved willow	*Salix myrtillifolia*	18	5.6	66.7
Jack pine	*Pinus banksiana*	12	25.0	66.7
Black spruce	*Picea mariana*	23	4.3	65.2
Bebb's willow	*Salix bebbiana*	14	0.0	64.3
Prickly rose	*Rosa acicularis*	16	25.0	50.0
Bunchberry	*Cornus canadensis*	11	18.2	45.5
Green alder	*Alnus viridis*	14	0.0	42.9
Mountain cranberry	*Vaccinium vitis-idaea*	18	0.0	33.3
Small cranberry	*Vaccinium oxycoccos*	12	33.3	33.3
Field horsetail	*Equisetum arvense*	17	5.9	23.5
Twinflower	*Linnaea borealis*	13	0.0	15.4
Red-stemmed feather moss	*Pleurozium schreberi*	10	0.0	0.0

Leaf mortality was most frequent in bog whortleberry (*Vaccinium uliginosum*; 46% of the sites it occurred in; Table 3-12), followed by small cranberry (*Vaccinium oxycoccos*; 33% of the sites it occurred in). Mortality was observed in 10 of the 15 species that were present in at least 10 sample sites.

Leaf damage (including leaf discolouration and fungus) was recorded for all species occurring in at least 10 sites, except for red-stemmed feather moss (*Pleurozium schreberi*; Table 3-12). The

species with the most frequent occurrence of leaf damage were Labrador tea (*Rhrododendron groenlandicum*) and fireweed (*Chamerion angustifolium*), at 85% and 79% of their sites, respectively (Table 3-12).

In combination, leaf mortality and damage was distributed throughout the sites at 100 m to 150 m for the 14 individual species that had either mortality or damage occurring in at least 10 sample sites (Table 3-13).

This was also the case for the percent of affected leaf. The species with the highest percentage of damaged leaf was myrtle-leaved willow (*Salix myrtillifolia*), which appeared to increase from an average of 7.6% of the leaf cover in sites at 100 m, to 33% in sites at 150 m (Table 3-13), however it is not known whether this is a significant difference due to the low number of samples at each distance. Small cranberry had the second-highest percentage of affected leaf, with 12% on average, but only at the 100m sites. The species with the highest percentage of leaf with mortality was Labrador tea, occurring at all distances, with the highest average occurring at 150 m. However, all of these numbers should be interpreted with caution because the replication at this scale was low.

Table 3-13: Percent of sites with leaf damage[1] and average percent of leaf cover affected[2] by species and distance from roadbed

Species	Statistic	Distance from Roadbed		
		100	125	150
Alnus viridis	Number of sites	3.0	4.0	3.0
	Percent of sites with damage	0.0	4.0	0.0
	Average percent of leaf cover damage	0.0	2.0	0.0
	Average percent of leaf cover with mortality	0.0	0.0	0.0
Chamerion angustifolium	Number of sites	4.0	2.0	5.0
	Percent of sites with damage	3.0	2.0	4.0
	Average percent of leaf cover damage	1.8	2.0	5.6
	Average percent of leaf cover with mortality	0.3	0.0	0.4
Cornus canadensis	Number of sites	1.0	2.0	3.0
	Percent of sites with damage	1.0	2.0	2.0
	Average percent of leaf cover damage	0.0	3.5	6.0
	Average percent of leaf cover with mortality	1.0	0.0	0.3
Equisetum arvense	Number of sites	4.0	4.0	5.0
	Percent of sites with damage	1.0	0.0	0.0
	Average percent of leaf cover damage	0.8	0.0	0.0
	Average percent of leaf cover with mortality	0.0	0.0	0.0
Linnaea borealis	Number of sites	3.0	3.0	3.0
	Percent of sites with damage	1.0	1.0	0.0
	Average percent of leaf cover damage	1.7	0.3	0.0
	Average percent of leaf cover with mortality	0.0	0.0	0.0
Picea mariana	Number of sites	6.0	4.0	1.0
	Percent of sites with damage	1.0	3.0	1.0
	Average percent of leaf cover damage	0.0	3.0	10.0
	Average percent of leaf cover with mortality	0.2	0.0	0.0
Pinus banksiana	Number of sites	3.0	4.0	1.0
	Percent of sites with damage	2.0	3.0	1.0
	Average percent of leaf cover damage	1.0	1.5	3.0
	Average percent of leaf cover with mortality	0.0	0.0	5.0

Species	Statistic	Distance from Roadbed		
		100	125	150
Rhododendron groenlandicum	Number of sites	17.0	15.0	14.0
	Percent of sites with damage	15.0	12.0	12.0
	Average percent of leaf cover damage	4.5	2.6	5.1
	Average percent of leaf cover with mortality	0.8	0.9	0.8
Rosa acicularis	Number of sites	4.0	3.0	3.0
	Percent of sites with damage	3.0	1.0	2.0
Rosa acicularis	Average percent of leaf cover damage	7.5	0.7	2.3
	Average percent of leaf cover with mortality	0.3	0.0	0.3
Salix bebbiana	Number of sites	2.0	2.0	3.0
	Percent of sites with damage	1.0	1.0	2.0
	Average percent of leaf cover damage	6.5	2.5	5.7
	Average percent of leaf cover with mortality	0.0	0.0	0.0
Salix myrtillifolia	Number of sites	5.0	4.0	3.0
	Percent of sites with damage	4.0	2.0	1.0
	Average percent of leaf cover damage	7.6	16.5	33.3
	Average percent of leaf cover with mortality	0.0	0.3	0.0
Vaccinium oxycoccos	Number of sites	6.0	3.0	2.0
	Percent of sites with damage	2.0	1.0	0.0
	Average percent of leaf cover damage	11.7	1.7	0.0
	Average percent of leaf cover with mortality	1.0	0.3	0.0
Vaccinium uliginosum	Number of sites	4.0	5.0	1.0
	Percent of sites with damage	1.0	4.0	1.0
	Average percent of leaf cover damage	1.3	3.0	1.0
	Average percent of leaf cover with mortality	0.3	6.2	0.0
Vaccinium vitis-idaea	Number of sites	5.0	6.0	4.0
	Percent of sites with damage	0.0	2.0	2.0
	Average percent of leaf cover damage	0.0	0.7	4.0
	Average percent of leaf cover with mortality	0.0	0.0	0.0

Notes: [1] Leaf discolouration and/or fungus. [2] Average percent foliage calculated from the maximum value for the site.

3.3 DUST ACCUMULATION

Requirements for the minimum number of days after a recent rainfall for dust accumulation data collection (Section 2.4.4) were not met during fieldwork in either July or August 2020.

During the first and second field tours, it was noted by the staff collecting the data that dust accumulation was not visible on leaves along the roadsides while conducting dust or other surveys along the NAR.

4.0 DISCUSSION

Dust accumulation data could not be collected in 2020 because it rained frequently. This was not considered to be a serious limitation to the interpretation of the other results for several reasons. Only three of the twelve road locations sampled in 2018 had road dust at sites further than 100 m. Also, the results showed that dust accumulations were readily removed from foliage by rain, indicating any observed accumulations were temporary and highly variable. Most importantly, the study's primary focus is to determine if there is evidence to suggest that road dust is adversely affecting vegetation that is more than 100 m from the road, and this evaluation is based on observed effects on vegetation.

One of the key factors that was assumed to influence the degree of road dust accumulation on vegetation was vegetation structure. It was expected that taller vegetation would intercept more dust particles, reducing dust accumulation at sites further from the source. Provided that dust was affecting vegetation health, it was expected that transects and sites with low vegetation structure types would have greater foliage damage or mortality further from the road. Overall, there was no statistically significant or even apparent difference between sites having different vegetation structure types with respect to the presence of foliage mortality or damage. This alone, however, does not preclude there being an effect on vegetation across all structure types. Taller, denser foliage may not effectively intercept smaller dust particles. One study by Mao et al. (2013) found through experiments and simulations that shelterbelts were not effective at intercepting the finer (~6 µm) road dust particles.

The observed seasonal increases in foliage mortality and damage were consistent with the literature. Chapin et al. (1975) reported that tundra vegetation showed an increasing proportion of the foliage biomass senescence as the growing season progressed. Shaver (1981, 1983) stated that for dwarf Labrador tea, leaf mortality over the growing season was common.

The pattern of leaf mortality and damage was not consistent with adverse effects from road dust. For transects with data starting at 50 m from the road (i.e., transects sampled in August), the average number of species with leaf mortality and leaf damage was highest at the 125 m sites and 150 m sites, respectively, rather than at 50 m. Furthermore, there was no statistically significant or even potential decreasing trend in either of these metrics.

For transects with data starting at 100 m from the road (transects sampled in both July and August), the average number of species with foliage damage and mortality showed a similar pattern to the August-only data. For both metrics, the average number of species with mortality and foliage damage was the highest at 125 m rather than 50 m, again with no apparent trends or statistical difference between the distances.

It was possible that some individual species may be more sensitive to dust accumulation than most others. Studies in Alaska found that as dust accumulations increased, sphagnum mosses, feather mosses and lichens and were the first species groups to be affected, followed by conifers and ericaceous shrubs (Auerbach *et al.* 1997; Myers-Smith *et al.* 2006; Walker and Everett 1987). In this study, red-stemmed feather moss was the only individual moss or lichen species occurring

in 10 or more sites that had no foliage mortality or damage. The species group (i.e., taxon) that included mosses that were not identified to species was present in most of the sites. However, foliage damage for this species group was recorded at only one site. Damage or mortality was rarely recorded for any of the other moss or lichen species. If dust accumulation has been affecting plants near the North Access Road, and it affects these species in the Project area similarly to other studies in northern areas, it would be expected that an effect would appear in these species, but none were observed.

Labrador tea was the species that most frequently had both leaf mortality and leaf damage. The effects of dust on other *Rhododendron* species (mainly dwarf Labrador tea (*Rhododendron tomentosum*, formerly *Ledum palustre*)) in road dust affected areas of Alaska are inconclusive (Farmer 1993). In this study, there was no decreasing trend in foliage damage or mortality with distance from the road. It is likely that the observed health conditions in this species were seasonal. Other studies show that dwarf Labrador tea leaf mortality during the growing season is common (Shaver 1981, 1983).

Because this was designed as a reconnaissance study, replication was not high enough to statistically test for distance from road effects on individual species. However, examination of the frequency of mortality and foliage damage, as well as the average proportion of foliage affected, did not suggest trends in foliage health related to distance from the road.

5.0 SUMMARY AND CONCLUSIONS

The EIS indicated that, while there may be localized areas where impacts or effects may extend more than 100 m from the Project footprint, the average distance of effects would be less than 100 m. Results from this study serve as a reconnaissance-level evaluation of the likelihood that road dust accumulation is impacting vegetation health at a greater distance from the Project footprint than predicted in the EIS.

Dust accumulation at a distance of more than 100 m from the roadbed was recorded at three out of 12 transects sampled in 2018, all of which were along the North Access Road. Dust accumulation data was not collected in 2020, as the rainfall criteria was not met during the sampling periods. This was not considered to be a limitation for several reasons, most importantly because the evaluation of whether or not road dust is adversely affecting vegetation is based on the observed effects on vegetation.

The monitoring found a natural, seasonal effect on overall foliage health. A higher proportion of sites sampled in August had foliage mortality and damage compared to sites sampled in July.

There were no statistically significant, or even suggestive, decreasing trends in foliage health with increasing distance from the road for any of the metrics used. These metrics included foliage health, the overall average of the maximum percent of affected foliage in each site, the average number of species with foliage mortality, and foliage mortality and damage for individual species.

Results from the dust on vegetation monitoring provided no suggestion that road dust has negatively affected vegetation more than 100 m from the access roads.

5.1 NEXT STEPS

This concludes this study as there was no evidence to suggest that road dust effects on vegetation were greater than assumed for the EIS.

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APPENDIX 1:
ADDITIONAL 2020 RESULTS

Table 6-1: Maximum leaf mortality (%) for all 22 transects, by transect and distance

Transect	Distance from Access road (m)[1]						
	50	100	125	150	175	200	225
DKN01	1	0	0	0			
DKN02	0	30	1	0			
DKN03	1	0	0	10	0		
DKN04	1	1	0	0			
DKN05	0	0	0	0	0		
DKN06	5	1	0	1	0	0	1
DKN07	1	1	30	0			
DKN08	1	5	5	2			
DKN09	0	0	0	0			
DKN10	10	1	0	0			
DKN11	0	0	0	0	0	0	
DKN12	2	1	0	0	0		
DKN13	0	0	0	0	0	0	0
DKN14	0	0	1	0			
DKN15	0	1	0	1			
DKN16	2	10	1	5			
DKN17	1	1	1	0			
DKN18	0	1	1	1			
DKN19	1	0	0	0			
DKN20	0	15	0	0			
DKN21	0	0	5	2			
DKN22	1	5	1	0			

Note: [1] Empty cells indicate that no site was sampled at that distance

Table 6-2: Maximum leaf damage (%) for all 22 transects, by transect and distance

Transect	Distance from Access road (m)1						
	50	100	125	150	175	200	225
DKN01	40	5	2	5			
DKN02	40	1	2	1			
DKN03	10	10	5	50	2		
DKN04	35	5	1	2			
DKN05	15	2	5	5	10		
DKN06	45	20	4	25		3	3
DKN07	15	10	10	15			
DKN08	5	20	5	15			
DKN09	5			3			
DKN10	40	35	2	2			
DKN11	5	1	3	1		1	
DKN12	5	2	20		1		
DKN13	15	5	5	1	3	5	1
DKN14	5	2	3	1			
DKN15	5	10	5	5			
DKN16	40	50	50	3			
DKN17	25	10	15	50			
DKN18	5	15	5	15			
DKN19	10	25	2	40			
DKN20	25	20	5	90			
DKN21	5	5	50	60			
DKN22	20	35	5	5			

Note: [1] Empty cells indicate that no site was sampled at that distance

Table 6-3: Analysis of variance of the mean maximum percent of foliage affected by mortality and damage for sites sampled[1] in different site level vegetation types

Site Structure Type	N	Mean	Standard Deviation
Foliage Damage			
Low	20	10.1	15.7
Tall Shrub	26	15.5	18.1
Treed	20	14.1	20.6
Significance		0.595	
Foliage Mortality			
Low	20	2.4	6.7
Tall Shrub	26	2.6	6.2
Treed	20	1.3	3.4
Significance		0.703	

Notes: [1] July and August sites from 100 m to 150 m only.

Table 6-4: Analysis of variance of the mean number of species with foliage mortality and damage for sites sampled in July and August starting at 100m for different distances from the road

Distance from Road (m) [1]	N	Mean	Standard Deviation
Foliage Damage			
100	22	42.3	22.2
125	22	50.7	24.8
150	22	48.3	28.8
Significance		0.535	
Foliage Mortality			
100	22	16.1	17.0
125	22	18.0	25.1
150	22	6.7	11.3
Significance		0.110	

Notes: [1] 175 m to 225 m sites not included because they were sampled in July only.

Table 6-5: Analysis of variance of the mean number of species with foliage mortality and damage for sites sampled in August starting at 50m for different distances from the road

Distance from Road (m)	N	Mean	Standard Deviation
Foliage Damage			
50	9	68.6	13.5
100	9	59.7	10.3
125	9	72.4	13.8
150	9	76.9	16.0
Significance		0.535	
Foliage Mortality			
50	9	20.7	25.1
100	9	23.0	17.4
125	9	37.6	27.3
150	9	12.0	15.1
Significance		0.110	

APPENDIX 2:
2020 SPECIES LIST

Table 6-6: List of species and pseudo-species recorded during 2020 surveys including number of sites where present

Common Name	Scientific Name	Number of Sites
Speckled Alder	*Alnus incana*	5
Green Alder	*Alnus viridis*	14
Alpine Bearberry	*Arctous alpina*	5
Dwarf Birch	*Betula pumila*	6
Bluejoint Reedgrass	*Calamagrostis canadensis*	2
Water Sedge	*Carex aquatilis*	2
Unidentified sedge	*Carex* spp.	11
Leather-leaf	*Chamaedaphne calyculata*	8
Fireweed	*Chamerion angustifolium*	19
Green reindeer lichen	*Cladonia arbuscula* ssp. *mitis*	4
Unidentified reindeer lichen	*Cladina* spp.	1
Unidentified cup lichen	*Cladonia* spp.	7
Bunchberry	*Cornus canadensis*	11
Black Crowberry	*Empetrum nigrum*	2
Field Horsetail	*Equisetum arvense*	17
Dwarf Scouring-rush	*Equisetum scirpoides*	8
Unidentified horsetail	*Equisetum* spp.	3
Woodland Horsetail	*Equisetum sylvaticum*	3
Smooth Wild Strawberry	*Fragaria virginiana*	2
Northern Comandra	*Geocaulon lividum*	2
Unidentified grass	Grass spp.	1
Stairstep Moss	*Hylocomium splendens*	7
Unidentified rush	*Juncus* spp.	1
Bog-laurel	*Kalmia polifolia*	2
Tamarack sapling	*Larix laricina* sapling	2
Tamarack seedling	*Larix laricina* seedling	1
Tamarack tree	*Larix laricina* tree	2
Twinflower	*Linnaea borealis*	13
Mountain-fly-honeysuckle	*Lonicera villosa*	1
Stiff Club-moss	*Lycopodium annotinum*	2
Ground-pine	*Lycopodium dendroideum*	1

Common Name	Scientific Name	Number of Sites
Two-leaved Solomon's-seal	*Maianthemum canadense*	4
Three-leaved Solomon's-seal	*Maianthemum trifolium*	1
Green-tongue Liverwort	*Marchantia polymorpha*	1
Tall Lungwort	*Mertensia paniculata*	1
Mitrewort	*Mitella nuda*	1
Unidentified moss	Moss spp.	71
White-grained Mountain-ricegrass	*Oryzopsis asperifolia*	1
Unidentified frog's-pelt	*Peltigera* spp.	2
Vine-leaved Colt's-foot	*Petasites frigidus* var. *x vitifolius*	1
Palmate-leaved Colt's-foot	*Petasites frigidus* var. *palmatus*	2
Arrow-leaved Colt's-foot	*Petasites frigidus* var. *sagittatus*	1
Black spruce sapling	*Picea mariana* sapling	12
Black spruce seedling	*Picea mariana* seedling	7
Black spruce tree	*Picea mariana* tree	4
Jack pine sapling	*Pinus banksiana* sapling	5
Jack pine tree	*Pinus banksiana* tree	7
Red-stemmed feather moss	*Pleurozium schreberi*	10
Juniper Haircap Moss	*Polytrichum juniperinum*	3
Balsam poplar sapling	*Populus balsamifera* sapling	3
Balsam poplar tree	*Populus balsamifera* tree	3
Trembling aspen sapling	*Populus tremuloides* sapling	2
Trembling aspen seedling	*Populus tremuloides* seedling	1
Trembling aspen tree	*Populus tremuloides* tree	3
Labrador tea	*Rhododendron groenlandicum*	61
Wild Red Currant	*Ribes triste*	3
Prickly rose	*Rosa acicularis*	16
Stemless Raspberry	*Rubus arcticus* ssp. *acaulis*	4
Cloudberry	*Rubus chamaemorus*	6
Red Raspberry	*Rubus idaeus*	1
Shrubby Willow	*Salix arbusculoides*	2
Bebb's willow	*Salix bebbiana*	14
Smooth Willow	*Salix glauca*	1
Myrtle-leaved Willow	*Salix myrtillifolia*	18

Common Name	Scientific Name	Number of Sites
Plane-leaved Willow	*Salix planifolia*	6
Myrtle-leaved Willow	*Salix pseudomyrsinites*	3
Unidentified willow	*Salix* spp.	4
Soapberry	*Shepherdia canadensis*	2
Unidentified goldenrod	*Solidago* spp.	1
Unidentified sphagnum moss	*Sphagnum* spp.	7
Snowberry	*Symphoricarpos albus*	1
Lindley's Aster	*Symphyotrichum ciliolatum*	6
Velvet-leaf Blueberry	*Vaccinium myrtilloides*	1
Small Cranberry	*Vaccinium oxycoccos*	12
Bog Whortleberry	*Vaccinium uliginosum*	13
Mountain cranberry	*Vaccinium vitis-idaea*	18
Mooseberry	*Viburnum edule*	3
American Purple Vetch	*Vicia americana*	1
Unidentified violet	*Viola* spp.	3