Semi-Automated Lineal Inventory of approximately 700,000 hectares in the Berland Smoky RAD Plan area of West-central Alberta – for 2012HSP6267.

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Abstract

A semi-automated lineal inventory was carried out for a large area within the Regional Access Development (RAD) boundary for the Foothills Landscape Management Forum (FLMF). Lineal disturbances (seismic lines, pipelines and well sites) where identified and spatially located using digital aerial photography. Ecological data and vegetation height and percent cover data was modelled, either through existing models or new models developed specifically for this project.

A total of 9,693 ha of the approximate 700,000 total ha of the project area had lineal disturbances. This represents about ½ of a percent of the total project area. Of this approximately one-quarter (25%) of the area has considerable amounts of natural regeneration on it. A significant portion, about 16%, also has no to poor natural regeneration currently growing on it.

The information used from this inventory will be crucial for managing the future use and mitigation of lineal disturbances within this region.

1.0 INTRODUCTION

A semi-automated method to inventory lineal disturbance features (seismic, pipelines and well-sites) using aerial-photography and LiDAR data is reported.

A detailed interpreted inventory was collected for the Little Smoky caribou range in 2010 (GreenLink, 2010). This project will expand on this work to the boundaries of the Regional Access Development (RAD) plan (Figure 1).

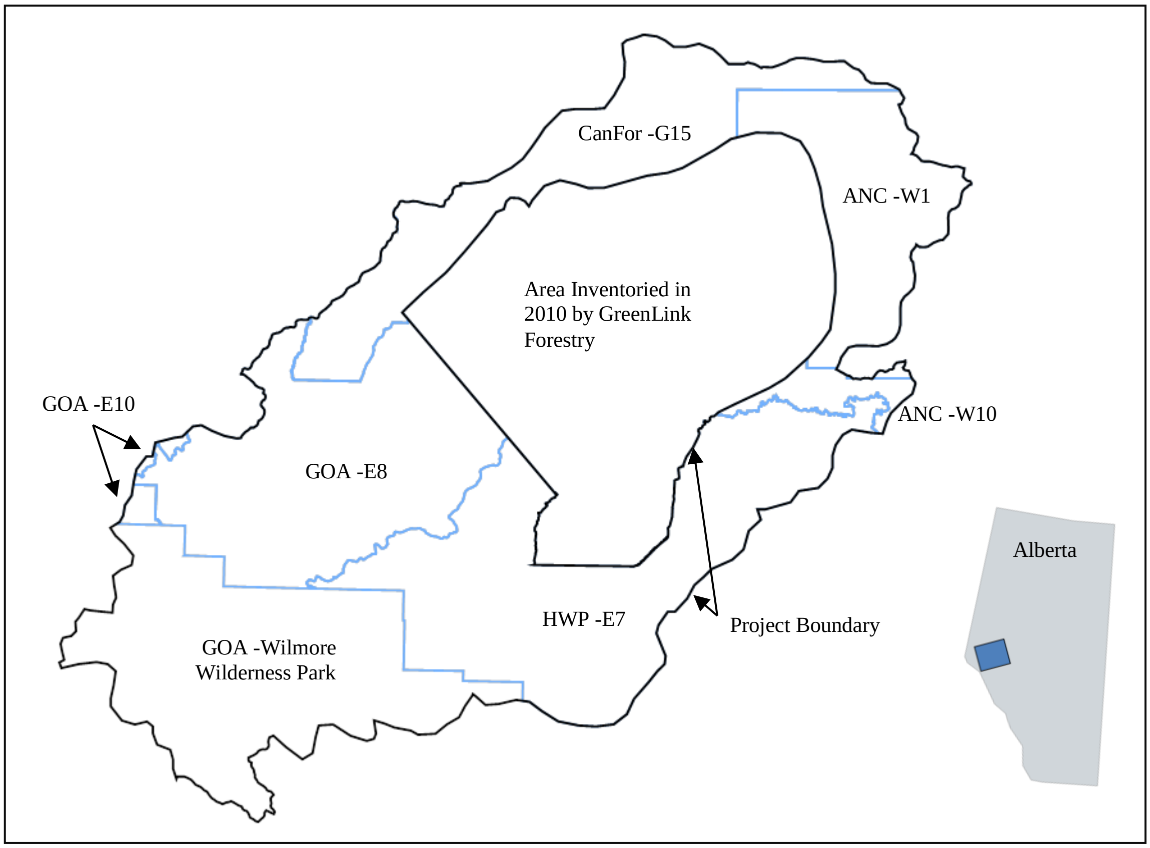

Figure 1. Inventory region
Blue internal lines are FMU boundaries

With GreenLink's (2010) inventory, a multitude of attributes were interpreted in softcopy, which, although provided a high resolution inventory, was a time-consuming and expensive endeavor. For this inventory, lineal disturbances were spatially referenced in softcopy but no attributes interpreted, except for line-width. Following this, select lineal attributes were modelled using either existing models or development of new models. This inventory therefore had less resolution but was more cost-effective as over twice the area was inventoried in about a third of the time it took to collect the 2010 inventory.

The main essential attributes modelled were ecosite (including slope and aspect), vegetation height and vegetation percent cover. Ecosite data is based on Alberta's ecosite field guides (Beckingham and Archibald 1996; Beckingham, Corns and Archibald 1996) and is essential to determine the best reclamation method. Much of the ecological inventory data for this project came from existing ecological models. Vegetation data determines the current state of the lineal feature and thus will help focus dollars to priority areas. Vegetation height and percent cover is modelled exclusively from LiDAR data.

2.0 METHODS

The methods used to generate the lineal inventory can be described in the following steps:

Step-1. Delineate lineal features in softcopy

Step-2. Expand polylines to polygons.

Step-3. Generate ecosite map data

Step-4. Generate vegetation, slope and aspect metrics using LiDAR data

2.1 DELINEATE LINEAL FEATURES IN SOFTCOPY

Seismic lines, pipelines and well sites were delineated in the Softcopy environment using the DATEM 3D viewer synchronized with ArcMap (v9) GIS software. The GIS format used was an ESRI shapefile, having a **poly-line** feature type format.

Orthophotos were used to locate lineal disturbances but not to spatially reference them. LiDAR data was used to both identify and spatially reference the Lineal disturbances (Figure 2). LiDAR was used as the spatial reference instead of Orthophoto data because the vegetation metrics were predicted using LiDAR data.

In ArcMap, all polylines were created as close to the centre of the lineal disturbance as possible. No attributes were collected except for line width (to the nearest 1 metre) which was estimated and would be used to convert the polyline shape file to a polygon shapefile (next step below).

The polyline layer was screened for completeness and correctness to the centre of the disturbance.

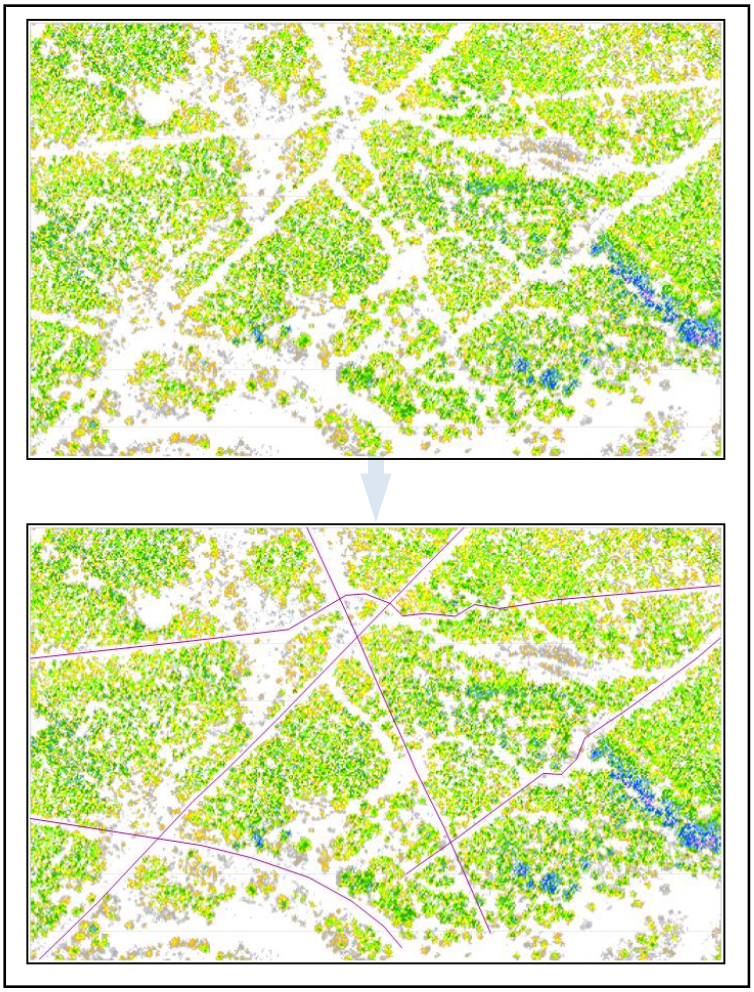

Figure 2. Example how poly-lines were spatially referenced to disturbance features interpreted from a LiDAR generated Canopy Height Model
The Canopy Height model is based on a 1 meter grid with heights coloured into 3 meter height classes

2.2 EXPAND POLYLINES TO POLYGONS

Polylines were converted to polygons using ArcMap (v10) software. The first step was to generate buffers around the polyline using the line width data collected by the interpreters during the delineation stage.

In order to control edge effect, which is the occurrence of non-disturbed vegetation being spatially located within the intended disturbed boundary, 1-meter was subtracted from the Line width before using it as a buffer parameter. Thus the buffer equation:

[1] Buffer = (Line Width - 1) * 0.5

Figure 3. Example showing poly-lines being converted to polygons
The Canopy Height model is based on a 1 meter grid with heights coloured into 3 meter height classes

2.3 GENERATE ECOSITE MAP DATA

The ecosite map information is based on Alberta's ecosite guides for Northern Alberta and West-Central Alberta (Beckingham and Archibald 1996; Beckingham, Corns and Archibald 1996, respectively). The map data came from four Sources (Figure 4):

1. Canadian Forest Products (Canfor)
2. Alberta Newsprint Company (ANC)
3. Hinton Wood Products (HWP)
4. Alberta Environment and Sustainable Resource Development (AESRD)

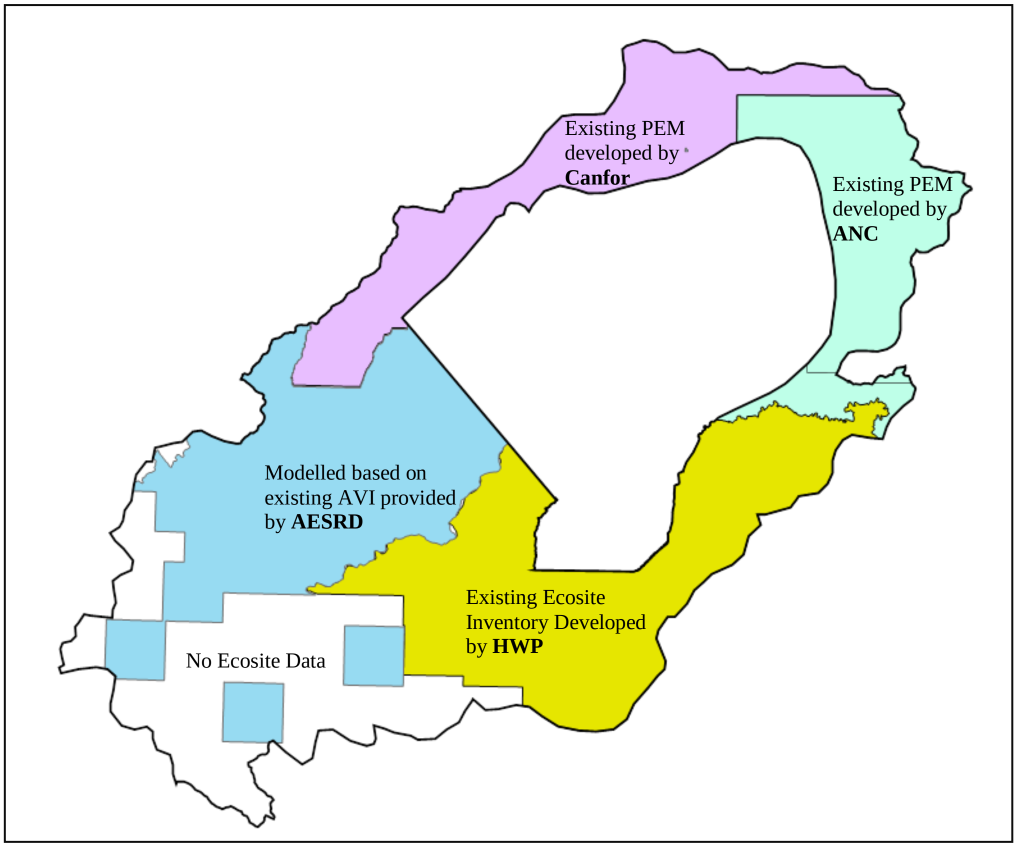

Figure 4. Map showing source of ecological data.

Ecosite maps already existed for Canfor, ANC and HWP. The maps for Canfor and ANC were the result of a Predictive Ecosite Mapping (PEM) process developed by Geographic Dynamics Corp (GDC) in the late 1990's. The HWP map was more of an inventory process, having a predictive element that relied on large amounts of field data. All three maps were integrated and used as received from the companies. i.e. no additional modifications or verification was carried out on the data.

No ecosite mapping data existed in FMU E8 or the Wilmore wilderness area (Wilmore). However AVI 2.1 data did exist for the entire E8 and a portion of Wilmore. The AVI data was used to predict ecosite based on assumed associations between vegetation species and site conditions. Although a significant portion of Wilmore does not have ecological data it is in an area with very little lineal disturbances.

2.3.1 Intersect with polygon data

Using ArcMap (v10) a spatial intersection was preformed with the ecosite map and lineal polygons produced in the previous step (Section 2.2 above) to produce a new thematic layer of lineal polygons having ecosite data and additional boundaries following the ecological boundaries (Figure 5). This "Lineal Ecosite" layer forms the base map for which the subsequent intersection with LiDAR data occurs (Section 2.4.1 below).

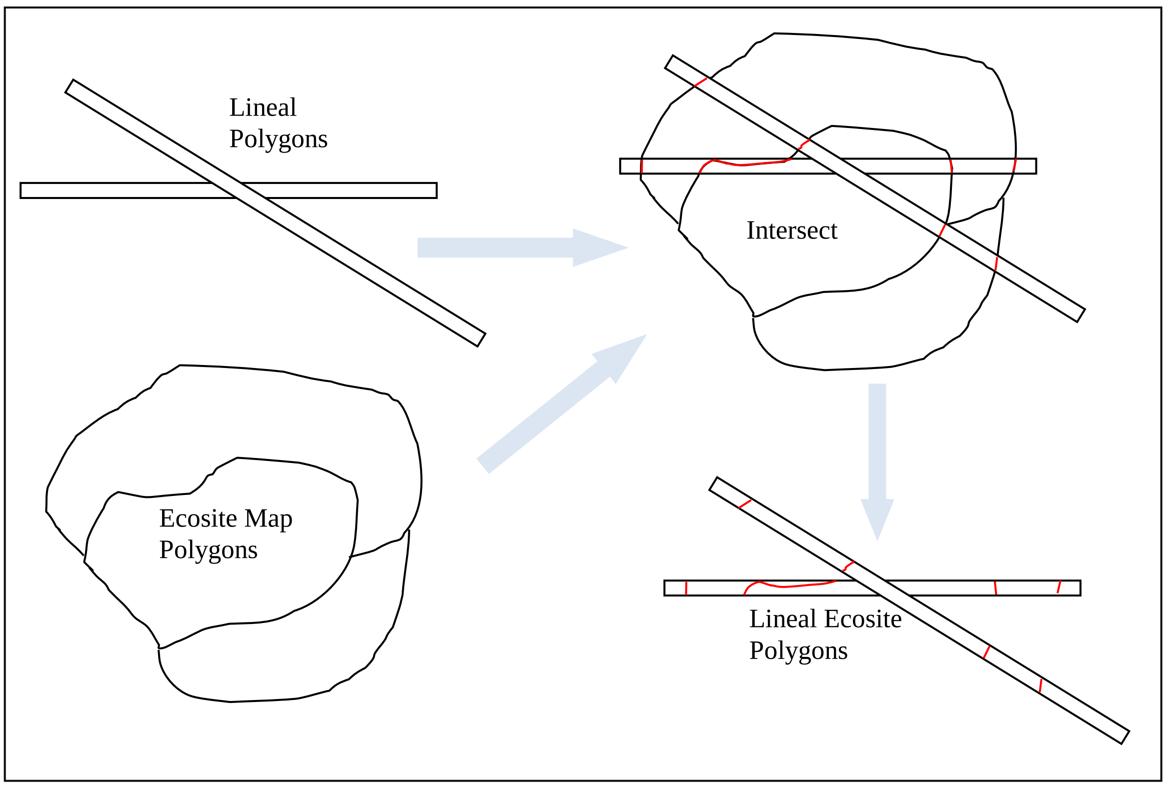

Figure 5. Schematic of the spatial intersection preformed with the ecosite map and lineal polygons

2.4 LIDAR DATA (HEIGHTS, SLOPE, ASPECT)

LiDAR data was used to generate vegetation metrics and was obtained from AESRD. The data was collected at a resolution of 1.2 to 1.8 returns per square meter and was flown between 2007 and 2009. LiDAR data was received by tiles (2km x 2km) labelled by the NTS location and date flown. For each tile area, two LiDAR derived grid files were processed to generate vegetation height: 1) Bare Earth and 2) Full Feature. Each file contained x, y and z values. The x and y represented UTM coordinates easting and northing (in meters), respectively. The z-value represented elevation (also in meters). The bare earth files represented ground returns. The full feature file represented the tallest vegetation structure returns.

Using SAS (v9) analytical software, vegetation heights were calculated simply by subtracting the bare earth z value from the full-feature z value along corresponding x & y axes. Slopes and Aspects were calculated from the bear earth simultaneously with heights and using algorithms described on ESRI's ArcMap website.

2.4.1 Intercepting lineal ecosite polygons with LiDAR data

The lineal ecosite polygon layer (created in the previous step, see Section 2.3 above) was intersected with height, slope and aspect data using SAS (v9.2) software. The result was a table having unique polygon numbers joined to x coordinates, y coordinates, height, slope and aspect data (Figure 6).

LINE #	X Coord.	Y Coord.	HEIGHT	SLOPE	ASPECT
45506	481107	5990502	0	6	192
45506	481107	5990503	0	7	192
45506	481107	5990504	7.2	7	203
45506	481107	5990505	16.7	6	210
45506	481107	5990506	11.7	3	209
45506	481107	5990507	0.2	1	79
45506	481107	5990508	0.1	2	40
45506	481107	5990509	0	2	16
27000	481107	5990510	0	1	301
27000	481107	5990511	0	3	227
27000	481107	5990512	0	4	212
27000	481107	5990513	0	5	197
27000	481107	5990514	0.1	5	186
27000	481107	5990515	0.3	4	180
27000	481107	5990516	5.4	4	178
27000	481107	5990517	11.4	4	180
27000	481107	5990518	16.3	2	184
27000	481107	5990519	9.3	1	177
27000	481107	5990520	0	2	163
300	481107	5990521	0	2	153
300	481107	5990522	4.6	2	158
300	481108	5990502	4.9	5	201
300	481108	5990503	3.3	7	191
300	481108	5990504	8.6	7	190
300	481108	5990505	7.9	4	189

Figure 6. Example of data table output from the spatial intersection of the lineal ecosite polygon layer with the height, slope and aspect data
The line-number [LINE #) is the unique polygon ID

2.4.2 Generating height, slope and aspect metrics.

Using the intersection output table (Figure 6 above) as the input table, the following metrics were calculated for each unique polygon using SAS (v9.2) software:

Height Metrics

- Mean and Standard Deviation of all heights in the polygon

- Mean and Standard Deviation of the tallest 1% of the heights in the polygon.
- Percent of the LiDAR returns in eight height classes

Slope Metrics

- Mean and standard deviation of all slope values in the polygon
- Percent of LiDAR returns in eight slope classes

Aspect

- Mean and standard deviation of all aspect values in the polygon
- Percent of LiDAR returns in eight aspect classes

Each variable calculated is described in more detail in the data dictionary section of this document.

2.5 EDGE

Edge is the incursion of adjacent non-disturbed vegetation into the disturbed polygon boundary (Figure 7). Although this does not need to be accounted for when calculating raw metrics it should be considered when generating some sort of meaningful index that relies on the raw vegetation metrics. It can be assumed that most edge occurs from taller tree crowns; although this should be validated sometime in the future.

If determining whether or not a particular lineal disturbance has an abundance of re-growth, one can account for edge by taken only those LiDAR returns under a certain height threshold. For example, since most lineal disturbances are at the most around 40 years old and since provincial site index equations would put most tree species from this time currently at heights between 12 to 16 meters any LiDAR returns above 12 meters can be ignored.

Another way edge can be accounted for is utilizing the information provided by the AVI data that exists in project region. AVI data has stand height and crown closure information that can potentially be used to filter LiDAR returns in the disturbed polygons that are actually the result of adjacent non-disturbed vegetation.

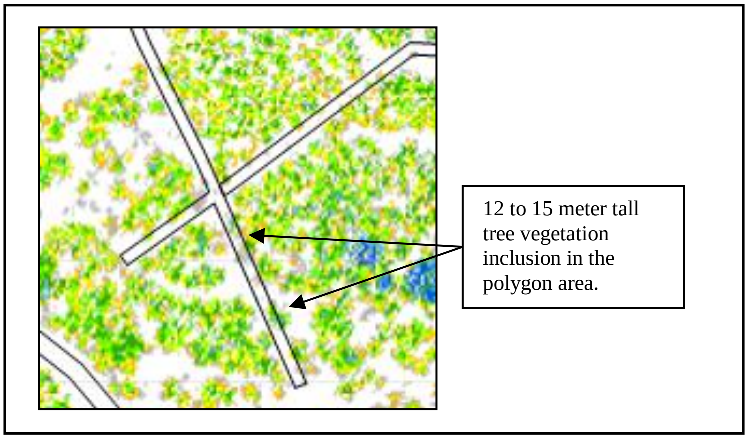

Figure 7. Example showing edge: adjacent non-disturbed vegetation being included in the disturbed polygon area

3.0 SPATIAL ATTRIBUTE DATA DICTIONARY

The following attributes are found in the ESRI shapefile delivered with this document.

NO.	ATTRIBUTE	FORMAT	DESCRIPTION
1	LNUMBER	integer	The unique polygon number
2	TYPE	Text	The Type of lineal disturbance: Seismic, Pipeline, Wellsite
3	SUBREGION	Text	The Natural Subregion the polygon is located in. Possible values are listed in Table 1 below.
4	ECO1, ECO2	Text	Primary (ECO1) and Secondary (ECO2) ecosites located in the polygon. Possible values are listed in Table 2 below
5	PHASE1, PHASE2	text	Primary (PHASE1) and Secondary (PHASE2) ecosite-phase as per Alberta's ecosite field guides.
6	MEAN_HT	decimal	Mean of all vegetation-height returns to the nearest 1/10th of a metre
7	STD_HT	decimal	Standard deviation of all vegetation-height returns to the nearest 1/10th of a metre
8	MEAN_SLP	integer	Mean all slope returns to the nearest 1 degree
9	STD_SLP	integer	Standard deviation all slope returns to the nearest 1 degree
10	MEAN_ASP	integer	Mean all aspect returns to the nearest 1 degree
11	STD_ASP	integer	Standard deviation of all aspect returns to the nearest 1 degree
12	N	integer	The number of returns used in the calculation of MEAN_HT and STD_HT
13	UP_MEAN_HT	decimal	Mean height of the tallest 1% of vegetation-height returns to the nearest 1/10th of a metre
14	UP_STD_HT	decimal	The standard deviation of the tallest 1% of vegetation-height returns to the nearest 1/10th of a metre

NO.	ATTRIBUTE	FORMAT	DESCRIPTION
15	UP_N	integer	The number of returns used in the calculation UP_MEAN_HT and UP_STD_HT
16	C0_01m	integer	The percentage (to the nearest 1 %) of returns between 0 and 0.1 metres.
17	C01_1m	integer	The percentage (to the nearest 1 %) of returns between 0 .0 and 1 metres.
18	C1_2m	integer	The percentage (to the nearest 1 %) of returns between 1 and 2 metres.
19	C2_3m	integer	The percentage (to the nearest 1 %) of returns between 2 and 3 metres.
20	C3_4m	integer	The percentage (to the nearest 1 %) of returns between 3 and 4 metres.
21	C4_5m	integer	The percentage (to the nearest 1 %) of returns between 4 and 5 metres.
22	C5_6m	integer	The percentage (to the nearest 1 %) of returns between 5 and 6 metres.
23	C6m	integer	The percentage (to the nearest 1 %) of returns greater than 6 metres.
24	S00_00	integer	The percentage (to the nearest 1 %) of returns that have zero slopes
25	S00_05	integer	The percentage (to the nearest 1 %) of returns that have between 0 and 5 degree slopes
26	S05_10	integer	The percentage (to the nearest 1 %) of returns that have between 5 and 10 degree slopes
27	S10_15	integer	The percentage (to the nearest 1 %) of returns that have between 10 and 15 degree slopes
28	S15_20	integer	The percentage (to the nearest 1 %) of returns that have between 15 and 20 degree slopes
29	S20_30	integer	The percentage (to the nearest 1 %) of returns that have between 20 and 30 degree slopes
30	S30_50	integer	The percentage (to the nearest 1 %) of returns that have between 30 and 50 degree slopes
31	S>50	integer	The percentage (to the nearest 1 %) of returns that have greater than 50 degree slopes
32	N		The percentage (to the nearest 1 %) of returns that have Northerly aspects
33	NE	integer	The percentage (to the nearest 1 %) of returns that have North-easterly aspects
34	E	integer	The percentage (to the nearest 1 %) of returns that have Easterly aspects
35	SE	integer	The percentage (to the nearest 1 %) of returns that have South-easterly aspects
36	S	integer	The percentage (to the nearest 1 %) of returns that have Southerly aspects
37	SW	integer	The percentage (to the nearest 1 %) of returns that have

NO.	ATTRIBUTE	FORMAT	DESCRIPTION
			South-westerly aspects
38	W	integer	The percentage (to the nearest 1 %) of returns that have Westerly aspects
39	NW	integer	The percentage (to the nearest 1 %) of returns that have North Westerly aspects

Table 1. List of Natural Subregion codes

DATABASE CODE	NATURAL SUBREGION
AL	Alpine
SA	Subalpine
MN	Montane
UF	Upper Foothills
LF	Lower Foothills
LBH	Lower Boreal Highlands
UBH	Upper Boreal Highlands
CM	Central Mixedwood
DM	Dry Mixedwood
FP	Foothills Parkland
PRP	Peace River Parkland

Table 2. List of ecosite codes

ECOSITES OF NORTHERN ALBERTA			ECOSITES OF WEST-CENTRAL ALBERTA		
NSR	LETTER	LABEL	NSR	LETTER	LABEL
Boreal Mixedwood	a	lichen	Lower Foothills	a	grassland
	b	blueberry		b	bearberry/lichen
	c	Labrador tea-mesic		c	hairy wild rye
	d	low-bush cranberry		d	Labrador tea-mesic
	e	dogwood		e	low-bush cranberry
	f	horsetail		f	bracted honeysuckle
	g	Labrador tea-subhygric		g	meadow
	h	Labrador-tea/horsetail		h	Labrador-tea/subhygric
	i	bog		i	horsetail
	j	poor fen		j	Labrador-tea/horsetail
	k	rich fen		k	bog
	l	marsh		l	poor fen
	m*	grassland		m	rich fen
	n*	meadow		n	marsh
Boreal Highlands	a	bearberry	Upper Foothills	a	grassland
	b	blueberry		b	bearberry/lichen
	c	Labrador tea-mesic		c	hairy wild rye
	d	low-bush cranberry		d	Labrador tea-mesic
	e	fern		e	low-bush cranberry
	f	horsetail		f	bracted honeysuckle
	g	Labrador tea-hygric		g	meadow
	h	bog		h	Labrador-tea/subhygric
	i	poor fen		i	Labrador-tea/horsetail
	j	rich fen		j	horsetail
	k*	grassland		k	bog

ECOSITES OF NORTHERN ALBERTA

NSR	LETTER	LABEL
	l*	meadow
	m*	marsh
Sub-Boreal	a	bearberry
	b	Canada buffalo-berry
	c	Labrador tea-mesic
	d	horsetail
	e	Labrador tea-hygric
	f	bog
	g	poor fen
	h	rich fen
	i*	grassland
	j*	meadow
	k*	marsh

ECOSITES OF WEST-CENTRAL ALBERTA

NSR	LETTER	LABEL
	l	poor fen
	m	rich fen
	n*	marsh
Montane	a	grassland
	b	bearberry
	c	hairy wild rye
	d	dogwood
	e	meadow
	f	horsetail
	g	fen
	h	marsh
	i*	bog
Subalpine	a	grassland
	b	bearberry/lichen
	c	hairy wild rye
	d	rhododendron-mesic
	e	meadow
	f	rhododendron-subhygric
	g	horsetail
	h	bog
	i	fen
	j*	marsh

additional Ecosite not originally referenced in the ecosite field guide. Refer to next **section for details*

4.0 RESULTS

Spatial and tabular results are provided in Figure 8. A total of 9,693 ha of lineal disturbance was identified by our process. Of this over half (54.5%) was seismic lines followed by Well-Sites (26.2%) then pipelines (19.3%). The highest densities of seismic lines are in the south-east and north portions of the inventory region. The Wilmore clearly has very little lineal footprint compared to the remaining area.

TYPE	AREA (ha)	%
seismic	5,287	54.5
pipeline	1,871	19.3
well site	2,535	26.2
total	***9,693***	*100*

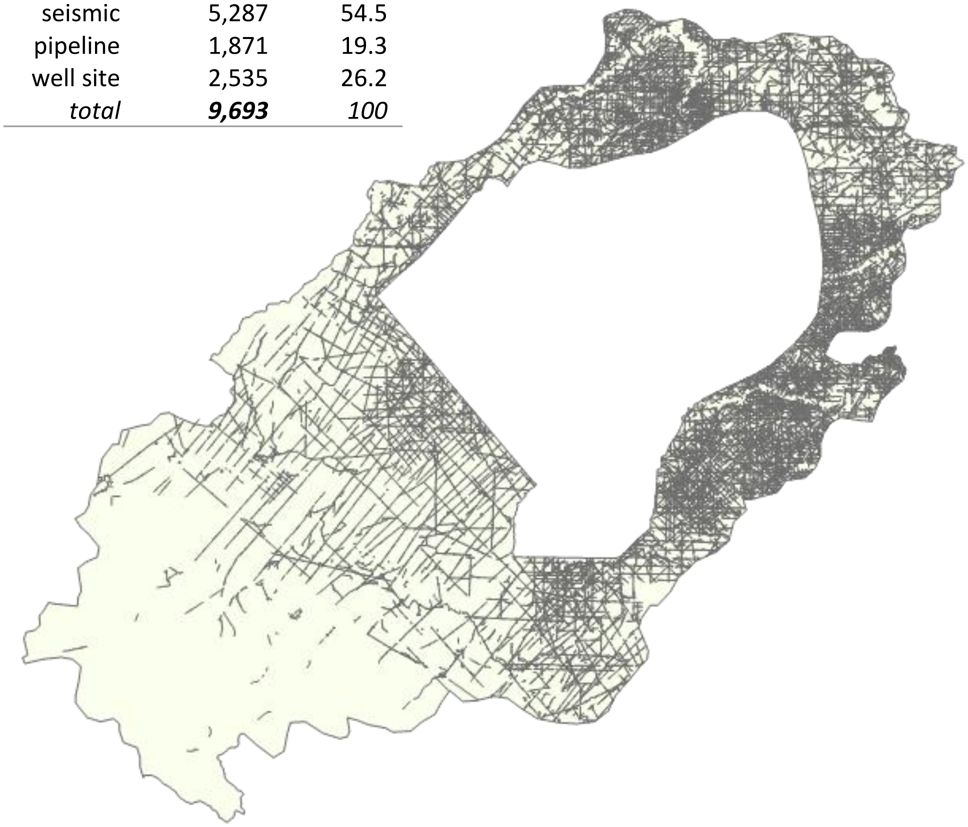

Figure 8. Map showing spatial extent of the lineal disturbance inventory
Associated table summarizes the area by disturbance type

4.1 VEGETATION STATUS

To determine the current vegetation status of the inventory area, a metric was devised based on five attributes (Numbers 18 to 22. See Data Dictionary, Section **Error! Reference source not found.**). For each polygon in the inventory, the percent cover of vegetation between 1 and 6 meters was calculated:

[2] C1_6m = C1_2m + C2_3m + C3_4m + C4_5m + C5_6m

Where: C1_6m = percent cover of vegetation between 1 and 6 meters tall

C1_2m = percent cover of vegetation between 1 and 2 meters tall

C2_3m = percent cover of vegetation between 2 and 3 meters tall

C3_4m = percent cover of vegetation between 3 and 4 meters tall

C4_5m = percent cover of vegetation between 4 and 5 meters tall

C5_6m = percent cover of vegetation between 5 and 6 meters tall

Values from variable C1_6m were categorized into the following broader groupings:

000	No Cover	Poor
001_010	> 0% & <10%	Low
010_020	>=10% & < 20%	Moderate
020_030	>=20% & < 30%	Good
030_040	>=30% & < 40%	Good
040_050	>=40% & < 50%	Excellent
>50	>= 50%	Excellent

The range between 1 and 6 meters was chosen because:

1. Vegetation returns above 1 meter are more meaningful towards current regeneration status.
2. The potential that many of the vegetation returns above 6 meters could be the result of edge.

The status of vegetation between 1 and 6 metres is presented in Table 3 and Figure 9. Almost half (about 47%) of the lineal disturbance area has at least moderate vegetation growth; at least 10% vegetation cover. A quarter (24%) of the area has good to excellent vegetation growth; at least 20% vegetation cover. Taking into account that the LiDAR was flown between 2007 and 2009 this shows that decent vegetation re-growth on many lineal disturbances is occurring naturally in many areas.

Table 3. Percent cover class distribution (by Area) of vegetation between 1 and 6 meters for the entire inventory area

% COVER CLASS	DESCRIPTION	AREA	%	REGENERATION RATING
000	no cover	1,624	16.8%	Poor
001_010	> 0% & <10%	3,480	35.9%	Low
010_020	>=10% & < 20%	2,232	23.0%	Moderate
020_030	>=20% & < 30%	1,028	10.6%	Good
030_040	>=30% & < 40%	561	5.8%	Good
040_050	>=40% & < 50%	319	3.3%	Excellent
>50	>= 50%	450	4.6%	Excellent
		9,694	100.0%	

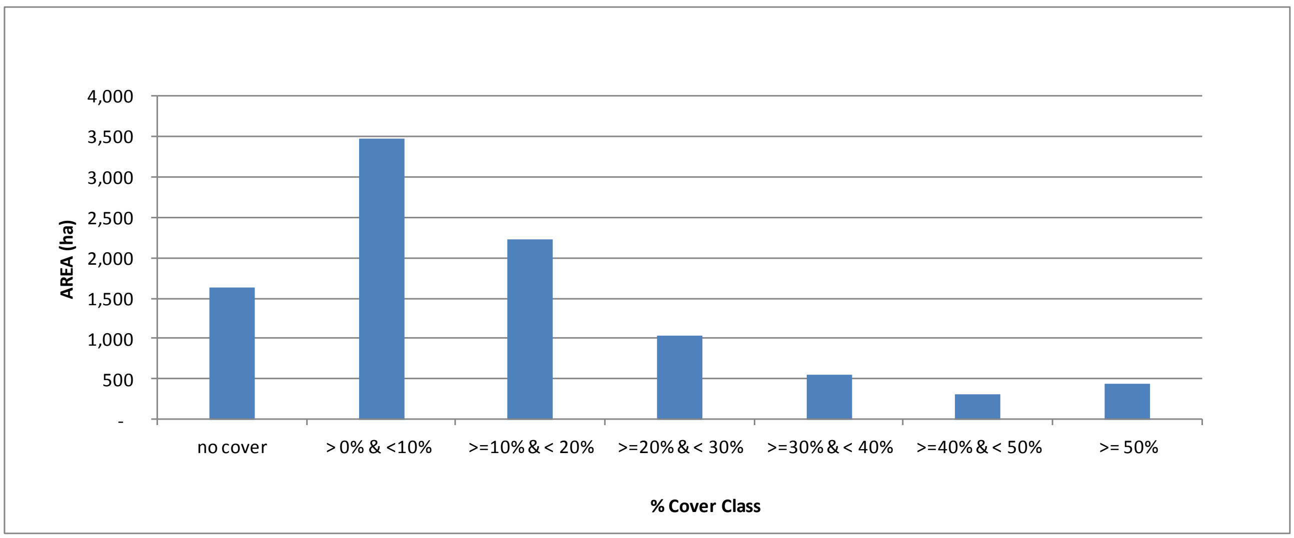

Figure 9. Bar Graph of Table 3 above.

4.2 ECOLOGICAL STATUS

To provide a meaningful assessment of the current ecolological status of the area, the primary ecosite (Variable No. 4, See Data Dictionary, Section 3.0) was categorized into the following broader edatopic groupings:

1. ANTH: No ecosite call as soil has been heavily disturbed
2. DRY: Sites having subxeric moisture regimes.
3. UPLAND-POOR: Mineral soil sites having submesic-subhygric moisture and poor nutrients
4. UPLAND MEDIUM: Mineral soil sites having submesic-subhygric moisture and medium nutrients
5. UPLAND-RICH: Mineral soil sites having mesic-subhygric moisture and rich nutrients
6. TRANSITIONAL-RICH: Mineral soil having organic layer between 10 and 40 cm and sites having subhygric to hygric moisture and medium to rich nutrients
7. LOWLAND: Organic soil having hygric to hydric moisture regimes

The groupings were then summarized over the landbase.

The ecological status of the inventory region is presented in Table 4 and Figure 10. Over a third (38%) of the inventory area has medium to rich upland sites, which provided optimum soil conditions for natural re-vegetation. Thus, mitigation effort on these sites should be low to none. Upland poor sites are the second most frequent site types, closely following upland medium sites. These sites could be considered the primary sites for mitigation since they are common and would respond adequately to remediation practices.

Table 4. Area distribution of ecological classes across the landbase.

ECO CLASS	DESCRIPTION	AREA	%	*Sites most likely to have good natural revegetation*
ANTH	No Ecosite Call	1,550	16.0%	
DRY	grassland and lichen sites	29	0.3%	
UPLAND-POOR	Lab tea- mesic + subhygric sites	2,960	30.5%	
UPLAND-MEDIUM	hairy-wild rye + modal sites	3,279	33.8%	
UPLAND-RICH	honeysuckle + meadow sites	417	4.3%	
TRANSITIONAL-RICH	horsetail sites	261	2.7%	
LOWLAND	bogs, fens & marshes	1,197	12.3%	
	Total	*9,693*	*100.0%*	

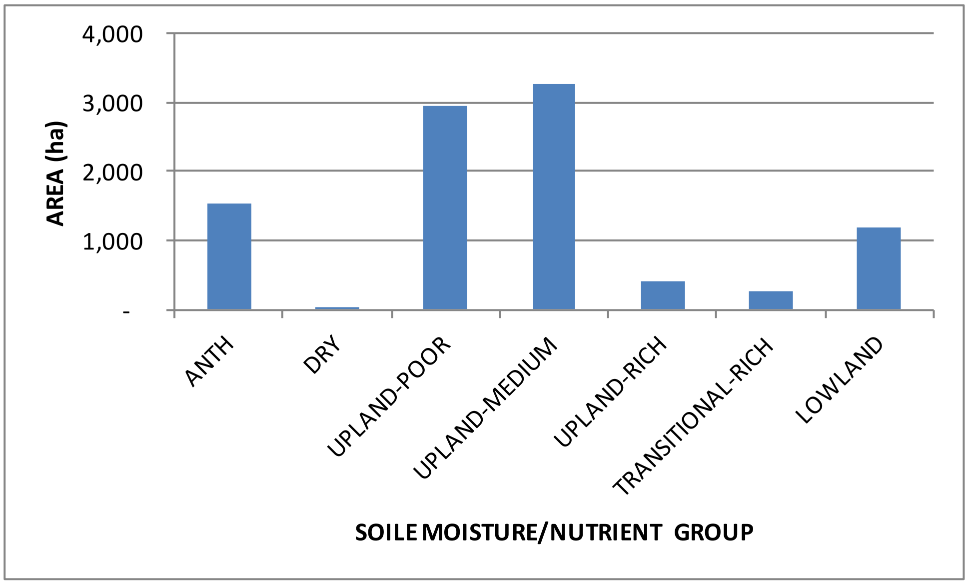

Figure 10. Bar Graph of Table 4 above

5.0 LITERATURE CITED

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