Environment Canada Environnement Canada

SCIENTIFIC ASSESSMENT TO INFORM THE IDENTIFICATION OF CRITICAL HABITAT FOR WOODLAND CARIBOU (*Rangifer tarandus caribou*), BOREAL POPULATION, IN CANADA

2011 UPDATE

Canada

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Appendix 7.2

7.2 Anthropogenic Disturbance Mapping Across Boreal Caribou (*Rangifer tarandus caribou*) in Canada – Mapping Process Documentation

1.0 PROJECT OUTLINE AND OBJECTIVES

As part of Environment Canada's efforts to provide additional information for the identification of boreal caribou critical habitat (this report), Environment Canada's Landscape Science and Technology Division was tasked with providing detailed anthropogenic disturbance mapping across known caribou ranges in order to better understand the attributes that have a known effect on caribou population persistence. This document outlines the steps used for mapping anthropogenic disturbances and the process established to create a nationally consistent, reliable and repeatable geospatial dataset that followed a common methodology. The methods developed were focused on mapping disturbances at a specific point of time, and were not designed to identify the age of disturbances, which can be of particular interest for those disturbances that can be considered non-permanent, for example cutblocks. The resultant dataset was used for two different purposes within the project: 1) for the meta-analysis and buffer sensitivity analysis; and 2) for the resource selection function and habitat modelling. While the general methods used for this work were identical for these two separate tasks some aspects did differ.

In work initially begun by Global Forest Watch Canada (GFWC), anthropogenic disturbances within 30 caribou ranges used for the development of a meta-analysis of boreal caribou population and habitat modelling (hereinafter referred to as meta-herds) across Canada were mapped. The meta-herds (Figure 23, Table 24) were defined by available information for caribou and disturbances were mapped across these areas using satellite imagery corresponding to the dates of the demographic data for each individual meta-herd. The resultant disturbance data was used in the buffer sensitivity analysis (Appendix 7.4) as well as the meta-analysis (Appendix 7.5).

Once mapping for the meta-herds was completed, further efforts were carried out in order to extend the mapping to cover full caribou local population boundaries, representing the full caribou range in Canada, as defined by each province or territory independently (Figure 24, Table 25). This mapping was carried out using 2008 to 2010 satellite imagery to provide the most up to date dataset possible. For local populations that overlapped meta-herd mapping, the previous mapping was updated where necessary by adding new disturbances that occurred after the original collection date, and which matched the meta-herd's demographic data. The resultant disturbance data was used in the dynamic habitat modelling (Appendix 7.7).

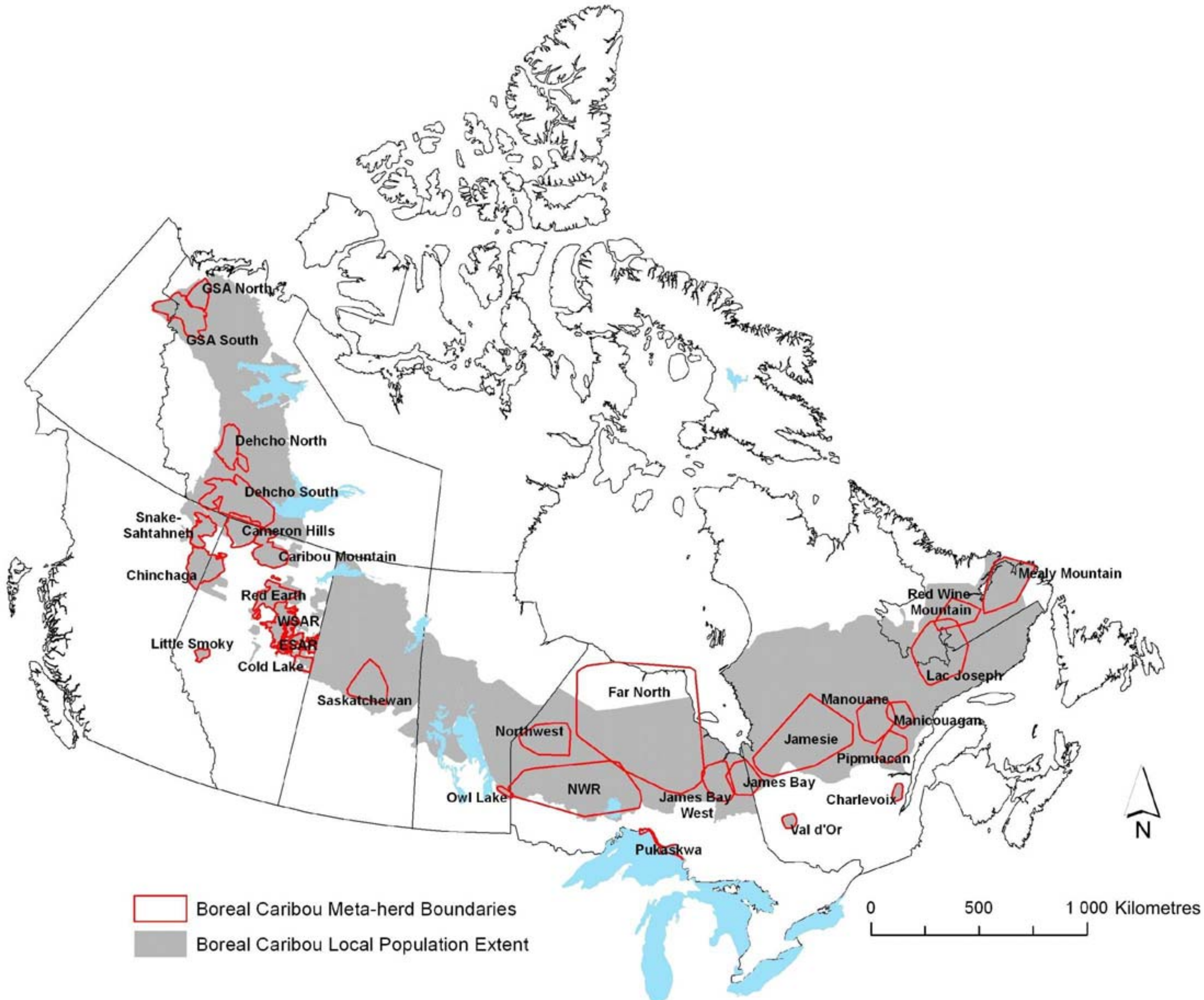


Figure 23. Boreal caribou meta-herds with full extent of boreal caribou local populations across Canada shown in background.

Table 24. Meta-herd name and dates of associated demographic data used to determine the date of the imagery used for the initial disturbance mapping.

Province / Territory	Herd Name	Demographic Data Used	Landsat Date Used
NWT	GSA South	2004–2006	2003–2005
NWT	GSA North	2005–2006	2005
NWT	Dehcho North	2006–2008	2006
NWT	Dehcho South	2006–2008	2006
NWT/AB	Cameron Hills	2006–2008	2006
AB	WSAR	2003–2006	2003
AB	Red Earth	2003–2006	2003
AB	Little Smoky	2003–2006	2003
AB	ESAR	2003–2006	2003
AB	Cold Lake	2002, 2004–2006	2002
AB	Caribou Mountain	2003–2006	2003–2004
AB/BC	Chinchaga	2003–2006	2003
BC	Snake-Sahtahneh	2004–2005	2004–2005
SK	Smoothstone-Wapawekka	1993–1995	1993
MN/ON	Owl Lake[1]	2002–2007	2001
ON	Pukaskwa[1]	1997, 1999, 2001	1997
ON	Far North[1]	2009	2008–2010
ON	James Bay West[1]	1998–2001 and 2006–2008	1998–2001 and 2009
ON	Northwest[1]	2009–2010	2009
ON	NWR[1]	1995–2006	1994–1995
ON/QC	James Bay	1998–2000	1998
QC	Val d'Or	2001–2002, 2004–2005	2001
QC	Pipmuacan	1999–2001	1999–2001
QC	Manouane	1999–2001	1999–2001
QC	Manicouagan	1999–2001	1999–2002
QC	Jamesie	2002–2003	2002
QC	Charlevoix	2001, 2004–2006	2001
NL	Mealy Mountain	2002, 2005	2002
NL	Red Wine Mountain	2001–2003	2000–2001
NL	Lac Joseph	2000–2002, 2005	2000–2002

1. Originally mapped to match available caribou locations used by resource selection function modelling.

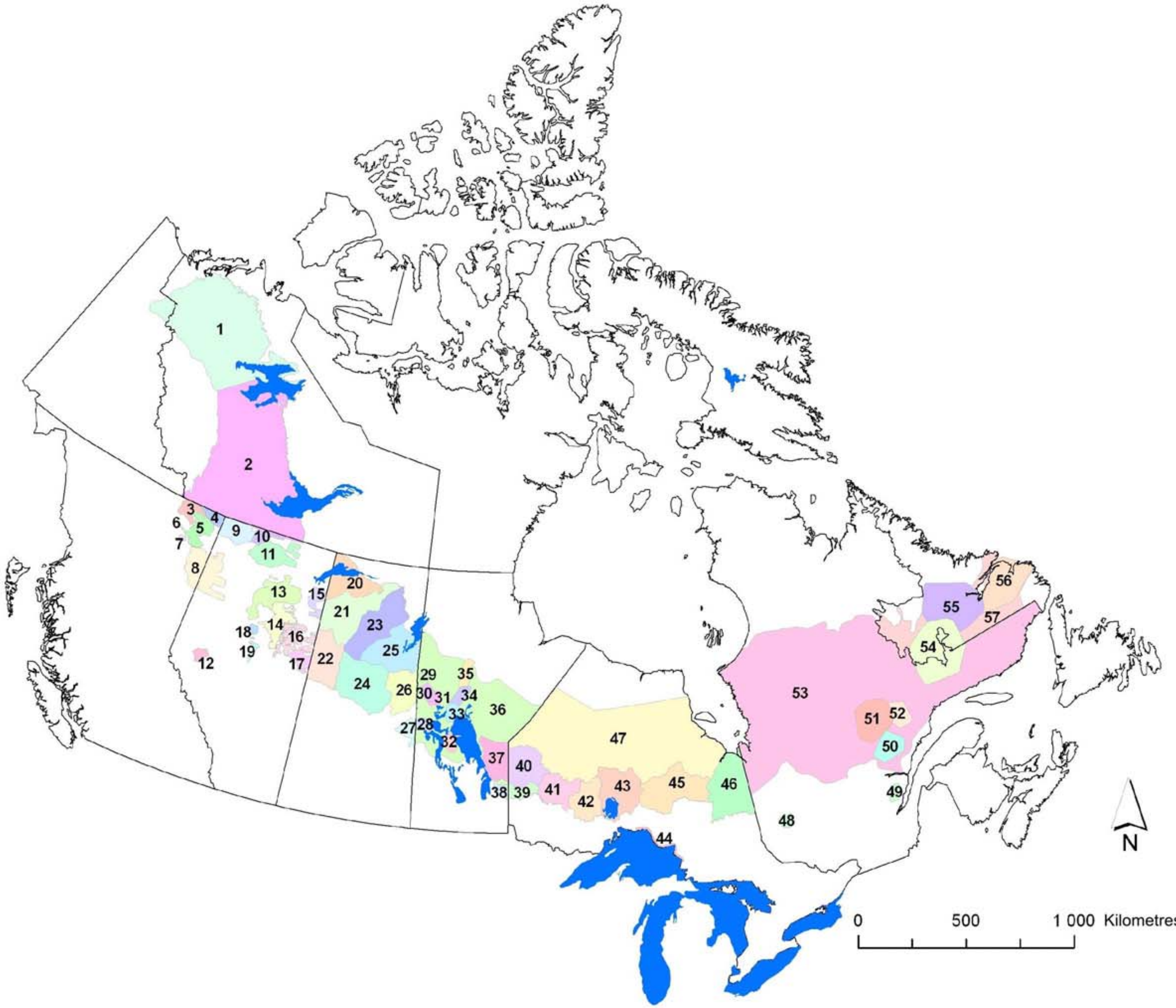


Figure 24. Boreal caribou Local Populations across Canada.

Table 25. Boreal caribou local population range name and ID number.

ID #	Local Population	Province / Territory	Area (ha)	Landsat Dates Used for Updated Mapping
1	Northwest Territories North	NWT	19 154 033	2009–2010
2	Northwest Territories South	NWT	24 398 791	2009–2010
3	Maxhamish	BC	710 105	2009–2010
4	Calendar	BC	496 392	2009
5	Snake-Sahtahneh	BC	1 198 752	2009
6	Parker	BC	22 452	2009
7	Prophet	BC	91 581	2009
8	Chinchaga	AB-BC	3 162 612	2009
9	Bistcho	AB	1 436 554	2008–2009
10	Yates	AB	523 094	2009
11	Caribou Mountains	AB	2 069 000	2009
12	Little Smoky	AB	308 606	2008–2010
13	Red Earth	AB	2 473 729	2009–2010
14	West Side Athabasca River	AB	1 572 652	2009–2010
15	Richardson	AB	707 349	2009
16	East Side Athabasca River	AB	1 315 980	2009–2010
17	Cold Lake	AB	672 422	2009–2010
18	Nipisi	AB	210 771	2009
19	Slave Lake	AB	151 904	2009
20	Davy-Athabasca	SK	3 186 753	2009–2010
21	Clearwater	SK	4 718 488	2009–2010
22	Primrose-Cold lake	SK	3 220 746	2009–2010
23	Highrock-Key	SK	4 393 300	2009–2010
24	Smoothstone-Wapawekka	SK	4 988 180	2008–2009
25	Steephill-Foster	SK	4 221 623	2009–2010
26	Suggi-Amisk-Kississing	SK	2 487 893	2009–2010
27	Pasqui-Bog	SK	682 435	2009
28	The Bog	MB	446 383	2010
29	Kississing	MB	317 026	2010
30	Naosap	MB	456 975	2009–2010
31	Reed	MB	357 425	2009–2010
32	North Interlake	MB	489 680	2009–2010
33	William Lake	MB	488 220	2009–2010
34	Wabowden	MB	628 959	2010
35	Wapisu	MB	565 044	2010
36	Manitoba	MB	14 958 366	2008–2010
37	Atikaki-Bernes	MB	2 114 072	2010
38	Owl-Flinstone	MB	363 568	2009
39	Sydney	ON	753 002	2010
40	Berens	ON	2 794 835	2010
41	Churchill	ON	2 150 492	2010
42	Brightsand	ON	2 220 921	2009–2010
43	Nipigon	ON	3 885 025	2008–2010
44	Coastal	ON	376 598	2008–2010

ID #	Local Population	Province / Territory	Area (ha)	Landsat Dates Used for Updated Mapping
45	Pagwachuan	ON	4 542 918	2009–2010
46	Kesagami	ON	4 766 463	2009–2010
47	Far North	ON	28 265 837	2008–2010
48	Val d'Or	QC	346 860	2009
49	Charlevoix	QC	312 799	2008
50	Pipmuacan	QC	1 376 911	2008–2009
51	Manouane	QC	2 716 459	2008–2009
52	Manicouagan	QC	1 134 113	2008–2009
53	Quebec	QC	62 156 148	2009–2010
54	Lac Joseph	LAB	5 802 361	2010
55	Red Wine Mountain	LAB	5 838 704	2006–2010[1]
56	Mealy Mountain	LAB	3 948 519	2009–2010
57	Labrador	LAB	5 177 322	2006–2010[1]

1. Due to cloud cover in this region, some imagery from 2006 and 2007 were needed, and as well current landsat 7 imagery was used in SLC off mode as a guide.

2.0 PROJECT SETUP AND BACKGROUND INFORMATION

2.1 Landsat Imagery

Landsat satellite imagery was selected for this project as the imagery provided enough spatial detail to identify disturbance features and provided full coverage of the areas of interest, usually with multiple dates available. The spatial resolution of all Landsat imagery used was 30 m with a positional accuracy of 50 m RMS (root mean square error). Image data for this project was sourced from the US Geological Survey (USGS) archived image library along with GFWC's Landsat image library. Landsat 5 and 7 imagery use was dependent on availability (Orthorectified product type L1T). Visible (Bands 1–3), near-infrared (Band 4) and mid-infrared (Bands 5 and 7) were all used for image interpretation.

2.2 Feature Definition

Within the context of this project, anthropogenic disturbance was defined as any human-caused disturbance to the natural landscape that could be visually identified from Landsat imagery at a viewing scale of 1:50 000. The use of a medium resolution sensor such as Landsat limited the size of features that could be seen and extracted, which was particularly evident in the underestimation of narrow seismic exploration lines (see Quality Assessment results in Section 4.2). As well, the limited spectral information provided by the optical sensor prevented differentiation between different seral stages of forests. Harvesting in some areas was missed as a result of regeneration and partial cutting, which after a certain time period makes the cut areas indistinguishable from the surrounding forest in the imagery. Disturbances mapped in this project are in fact current disturbances and it is acknowledged that older disturbances were missed in the mapping process.

For each anthropogenic feature type, a clear description was established to maintain consistency in identifying the various disturbances in the imagery by the different interpreters. Ancillary data was used to guide interpretation and feature labelling; however, because these ancillary data were often variable across the country in terms of completeness as well as scale, features were only digitized if they were clearly visible in the Landsat imagery at a viewing scale of 1:50 000. This general rule set the baseline for developing more specific rules of interpretation and digitizing disturbance events.

Each disturbance feature type was represented in the database by a line or polygon depending on their geometric description. Table 26 and Table 27 list the anthropogenic features of interest and their definitions. Users must keep in mind that this mapping was designed primarily for the purpose of the Boreal Caribou Critical Habitat Identification project and any use of this product beyond the intended scope should be done with caution.

2.3 Minimum Mapping Unit

2.3.1 Polygon Disturbances

The minimum mapping unit (MMU) represents the smallest polygonal feature that can be reliably interpreted and digitized on screen at a viewing scale of 1:50 000 in a false colour or natural colour composite Landsat scene. For this project a MMU of 2 ha or approximately 22 contiguous Landsat pixels (30 m x 30 m) was selected. The only exception to this rule was well sites that were represented by a 100 m diameter circle or a MMU of 0.785 ha (section 3.3.3 Rules Specific to Polygon Disturbances). The selected MMU is similar to the 2 ha standard set with 1:20 000 natural colour aerial photography used to produce the Alberta Vegetation Inventory (Government of Alberta, 2007).

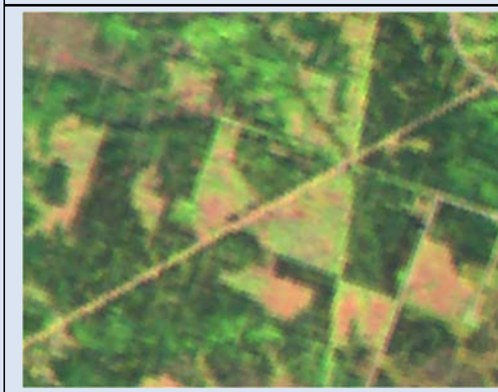
2.3.2 Minimum Separation Distance

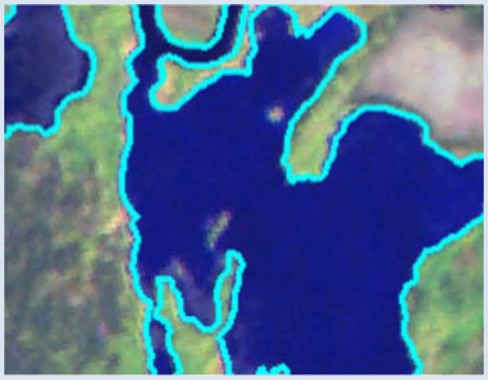
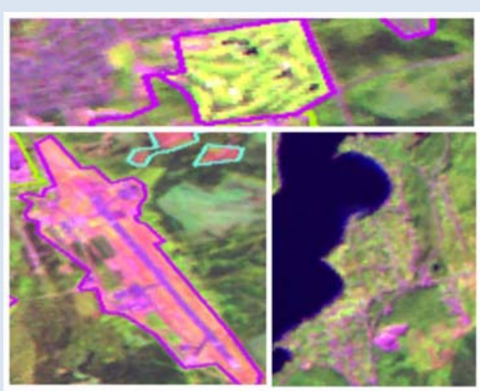
No standard minimum separation distance that would identify a disturbance as unique from neighbouring disturbances was established between mapped polygonal features. As a result, similar disturbances may have been mapped as multiple or single features depending on the individual interpreter's protocol. For linear features, a separation distance of approximately 100 m was typically used.

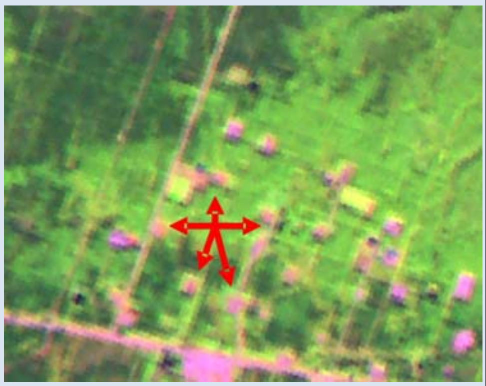
2.4 Ancillary Datasets

Various ancillary vector datasets were used as aids in detecting, classifying and digitizing disturbances on the Landsat imagery (Table 28). Ancillary data were used only as an aid to mapping and were never traced or "burned in" with only one exception. The exception was the Global Forest Watch Canada (GFWC) reservoir dataset (GFWC, 2009), which was burned in as a result of the complex nature of reservoir bounds, and the difficulty in identifying reservoirs compared with other water bodies. This was done to avoid unnecessary duplication of previous GFWC efforts.

Table 26. Polygonal anthropogenic features extracted from the imagery.

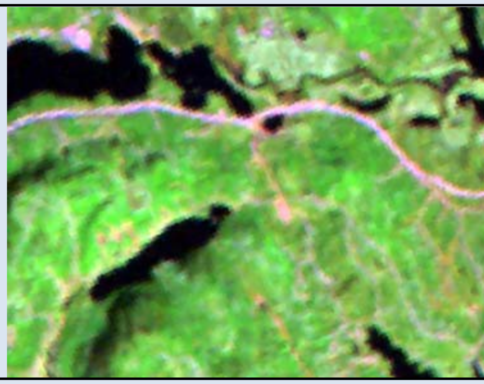
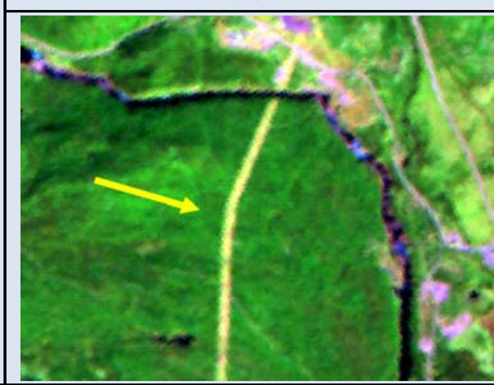
<table>
<tr><th>Polygonal Feature Type</th><th colspan="2">Land Use Definition and Feature Type Interpretation</th></tr>
<tr><td rowspan="4">Cutblock</td><td colspan="2">An area of land within a forested landscape that is actively managed for harvest operations. Cutblock areas can range from clear cut to partial or strip cuts depending on the management protocol.</td></tr>
<tr><td colspan="2">Typically square or rectangular in shape, but sometimes irregular in shape. Contextually located within a natural landscape and adjacent to or linked with a network of access roads. On false colour infrared composites recent cutblocks are bright blue changing to bright red following several years of regeneration. Cutblock identification becomes less reliable as time-since-disturbance increases. Partial cuts are not as easily identified as clear or strip cuts. No ancillary data were used to verify cutblocks.</td></tr>
<tr><td>Landsat bands 5,4,3 – scale 1:50 000</td><td>(VWS, 2010)</td></tr>
<tr><td></td><td></td></tr>
<tr><td rowspan="4">Mine</td><td colspan="2">Area of exposed land that is used associated with mineral or aggregate extraction operations, including: quarries, slag heaps, tailing piles, tailings ponds and associated mining infrastructure. Waste water and holding ponds associated with industrial activities, and any other artificial water bodies that were not true reservoirs, were included in this category.</td></tr>
<tr><td colspan="2">On false colour infrared composites exposed land and associated ponds are clearly visible. Gravel pits are typically located adjacent to roads. Mining operations will have permanent infrastructure while in operation. Generally irregular in shape. Identification of these often requires ancillary data when using Landsat imagery.</td></tr>
<tr><td>Landsat bands 3,2,1 – scale 1:50 000</td><td>(Charapay, 2010)</td></tr>
<tr><td></td><td></td></tr>
</table>

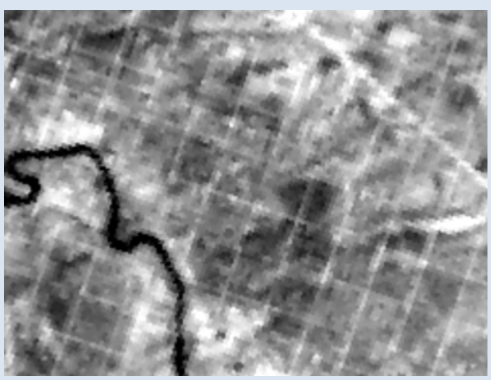
<table>
<tr><th>Polygonal Feature Type</th><th colspan="2">Land Use Definition and Feature Type Interpretation</th></tr>
<tr><td rowspan="4">Reservoir</td><td colspan="2">Reservoirs were defined as large bodies of water upstream of a known major dam location. These were primarily taken from the GFWC Reservoirs database</td></tr>
<tr><td colspan="2">Ancillary vector data were used to map reservoirs (GFWC, 2009)</td></tr>
<tr><td>Landsat bands 5,4,3 – scale 1:50 000</td><td>(Travel Pod, 2010)</td></tr>
<tr><td></td><td></td></tr>
<tr><td rowspan="4">Settlement</td><td colspan="2">A built-up area of infrastructure associated with urban areas such as cities, towns and villages. May include small groups of buildings that are not clearly associated with other feature types including larger airports, golf courses, industrial areas and water treatment plants. Does not include farmsteads or any infrastructure associated with agriculture.</td></tr>
<tr><td colspan="2">Typically bright areas in the imagery that is geometric in shape with a gridded pattern characteristic of residential areas. Larger clusters of buildings may be industrial or commercial areas. Lower density settlement associated with cottages or rural business may be classified through association, contextual information or ancillary data sources.</td></tr>
<tr><td>Landsat bands 5,4,3</td><td>(Ontario’s Historical Plaques, 2010)</td></tr>
<tr><td></td><td></td></tr>
</table>

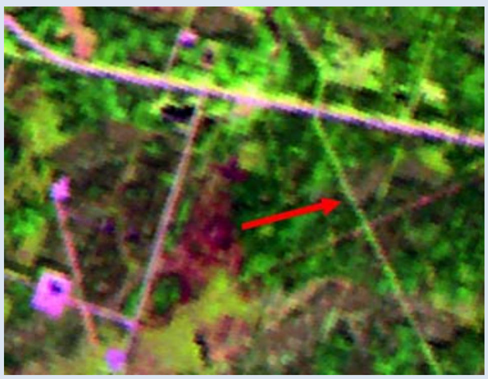
<table>
<tr><th>Polygonal Feature Type</th><th colspan="3">Land Use Definition and Feature Type Interpretation</th></tr>
<tr><td rowspan="5">Well Site</td><td colspan="3">Area of disturbed land associated with oil and gas development in terms of the location of well pads, well heads and the surrounding infrastructure. Does not include linear seismic lines or pipelines.</td></tr>
<tr><td colspan="3">Ancillary vector data were used to identify the majority of well sites established between 1901 and 2009 (IHS Energy, YEAR). Additional larger well site complexes were manually digitized if missed by the ancillary data. Well sites were identified as bright square shaped disturbances linked to a pipeline network.</td></tr>
<tr><td>Landsat bands 5,4,3 – scale 1:50 000</td><td rowspan="2"></td><td>(EVR, 2010)</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="3">Agriculture</td><td colspan="3">Includes all land that was cleared for cropland or pastureland including all infrastructure associated with agricultural activities, e.g. barns, homestead.</td></tr>
<tr><td colspan="3">Typically rectangular or square in shape and following property or road boundary. Hedge row or shelter belt may be visible between fields. Bright blue on a false colour composite if recently cleared or not vegetated. During the growing season may appear as bright red. Contextually located near other areas of agriculture.</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

<table>
<tr><th>Polygonal Feature Type</th><th colspan="3">Land Use Definition and Feature Type Interpretation</th></tr>
<tr><td rowspan="4">Oil and Gas</td><td colspan="3">Features associated with the oil and gas industry. This may include gas plant, batteries, pump station and compressor stations.</td></tr>
<tr><td colspan="3">Ancillary vector dataset was used to aid the identification of oil and gas facilities (UofA, 2009)</td></tr>
<tr><td>Landsat bands 5,4,3 – scale 1:50 000</td><td></td><td>(Petro Enerwest Canada, 2009)</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Unknown</td><td colspan="3">Areas believed to be anthropogenic disturbance, based on patterns and comparison to surrounding environment in the satellite imagery; however, the specific type of disturbance is unknown.</td></tr>
<tr><td>Landsat bands 3,2,1 – scale 1:50 000</td><td></td><td>Landsat bands 3,2,1 – scale 1:50 000</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

Table 27. Linear anthropogenic features extracted from the imagery.

<table>
<tr><th>Linear Feature Type</th><th colspan="3">Land Use Definition and Feature Type Interpretation</th></tr>
<tr><td rowspan="4">Road</td><td colspan="3">All road types regardless of classification, i.e. private forest, single paved or major highway etc. that could be interpreted from the Landsat imagery.</td></tr>
<tr><td colspan="3">Typically in a connected linear network, roads appear as bright features on a false colour composite image. All roads were digitized as a single vector line without differentiation of feature type or width. An ancillary vector dataset (DMTI CanMap Streefile, 2000) was used to help verify the presence of some roads, however, only those visible in the imagery were included in the final dataset.</td></tr>
<tr><td>Landsat bands 5,4,3 – scale 1:50 000</td><td></td><td>(North to Alaska, 2010)</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td rowspan="4">Powerline</td><td colspan="3">Infrastructure and the right-of-way corridor associated with the transmission of electrical power.</td></tr>
<tr><td colspan="3">Feature interpretation is generally through association or via the process of elimination using both image information and ancillary vector data. For example, a bright linear feature on the imagery that is connected to a hydro electric facility but is not part of the roads vector data layer would be labelled as a powerline.</td></tr>
<tr><td>Landsat bands 5,4,3 – scale 1:50 000</td><td></td><td>(CACC, 2010)</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

<table>
<tr><th>Linear Feature Type</th><th colspan="2">Land Use Definition and Feature Type Interpretation</th></tr>
<tr><td rowspan="4">Railway</td><td colspan="2">Any passenger and commercial railway lines that were visible in the Landsat imagery</td></tr>
<tr><td colspan="2">Railways and the associated right-of-way appeared as bright linear features on a false colour infrared composite image. Ancillary vector data were used for identification of this feature type (GeoGratis, 2008).</td></tr>
<tr><td>Landsat bands 5,4,3 – scale 1:50 000</td><td>(Canada Photos, 2010)</td></tr>
<tr><td></td><td></td></tr>
<tr><td rowspan="4">Seismic Line</td><td colspan="2">Linear features resulting from clearing and surface disturbance due to oil and gas and mineral exploration.</td></tr>
<tr><td colspan="2">Seismic lines were typically less than 10 m wide (CLMA and FPAC, 2007) but were partially visible in Landsat imagery linear features with medium to high brightness against contrasting darker forested pixels. These features may be confused with pipelines, but are generally narrower and have a lower contrast against neighbouring land cover in the imagery. Lines may appear broken across the landscape depending on the landcover adjacent to the seismic lines.</td></tr>
<tr><td>Landsat bands 5,5,5 – scale 1:50 000</td><td>(GFWC, 2010)</td></tr>
<tr><td></td><td></td></tr>
</table>

Linear Feature Type	Land Use Definition and Feature Type Interpretation	
Pipeline	Infrastructure for the transportation of gas or petroleum products including any adjacent cleared land associated with the right-of-way.	
	Feature Interpretation: Where available an ancillary dataset of existing pipelines was used to confirm pipelines. May be confused with seismic lines or roads. Generally wider and more distinct than seismic lines and can sometimes be separated from roads by the spectral reflectance where ancillary data or high resolution imagery is not available. An ancillary vector dataset was used to aid interpretation of pipelines.	
	Landsat bands 5,4,3 – scale 1:50 000	(Government of Alberta, 2010)
		
Dam	An obvious barrier constructed across a watercourse.	
	Depending on its size, dams are difficult to interpret from Landsat imagery. They appear as bright linear features bordering a section of a lake or river. Ancillary vector data was not available for dams.	
	Landsat bands 3,2,1 – scale 1:50 000	(EMPR, 2010)
		

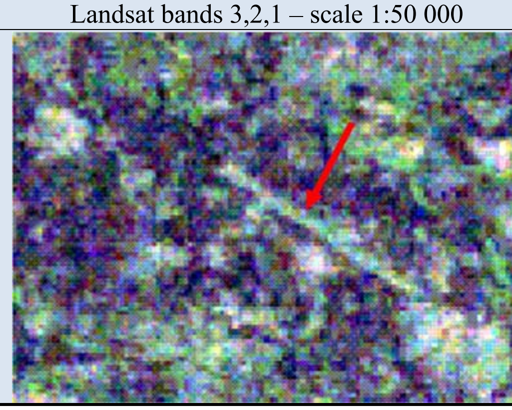
<table>
<tr><th>Linear Feature Type</th><th colspan="2">Land Use Definition and Feature Type Interpretation</th></tr>
<tr><td rowspan="4">Airstrip</td><td colspan="2">Runways used by aircraft. May include public and private airstrips not already associated with any surrounding settlement or infrastructure.</td></tr>
<tr><td colspan="2">Bright linear features several pixels wide. High contrast against adjacent land cover. Typically >250 m in length. In remote areas may not be connected to the primary road network but linked to resource roads.</td></tr>
<tr><td>Landsat bands 5,4,3 – scale 1:50 000</td><td>(DND, 2010)</td></tr>
<tr><td></td><td></td></tr>
<tr><td rowspan="3">Unknown</td><td colspan="2">Areas believed to be anthropogenic disturbance, based on patterns and comparison to surrounding environment in the satellite imagery; however the specific type of disturbance is unknown.</td></tr>
<tr><td>Landsat bands 3,2,1</td><td>Landsat bands 3,2,1 – scale 1:50 000</td></tr>
<tr><td></td><td></td></tr>
</table>

Table 28. Ancillary datasets, sources and descriptions.

Dataset Name	Source	Description	Date of Data Coverage
CanMap Streetfiles v2.0 Road Network	DMTI Spatial		2000
NRN Road Network	GeoBase	Various editions depending on provinces.	2008–2010
Statistics Canada Road Network	Statistics Canada		2010
Canada Well Sites	IHS Energy (Through University of Alberta)	Well site locations to be used for mapping purposes only.	2009
Utilities (power / pipelines) – VMAP	GeoGratis		2000
Atlas of Canada Railways	GeoGratis		2008
Major Reservoirs	GFWC	A national dataset of all major reservoirs developed from a variety of sources.	2009
National Large Fire Database	NRCAN		2009
Active Metal Mines	GFWC	This data gives an indication of areas where mining has a significant economic and environmental impact.	2008
Designated Places	Statistics Canada	Small communities and settlements, generally too small to be considered "urban areas"	2006
Urban Areas	Statistics Canada	As defined from 2006 census – populated places with minimum 1000 people and 400 people per square kilometre.	2006
BC Cutblocks	GeoBC	https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=50580&recordSet=ISO19115	2010
BC Forestry Roads	GeoBC	https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=45694&recordSet=ISO19115	2010
BC Petroleum Development Roads	Oil and Gas Commission (OGC)	http://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordSet=ISO19115&recordUID=58803	2010
BC seismic	Oil and Gas Commission(OGC)	http://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=58781&recordSet=ISO19115	2009
BC pipelines	GeoBC	http://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=58741&recordSet=ISO19115	2010
AB facilities	IHS Energy (Through University of Alberta)	This data is a spatial representation and should be used for mapping purposes only.	2009?
AB Pipelines	IHS Energy (Through University of Alberta)	This data is a spatial representation and should be used for mapping purposes only.	2009?

2.5 Geodatabase Setup

ArcGIS 9.3 and 10.0 was used for all geodatabase creation and data collection, with ArcInfo license (ESRI 2009; 2010) used for all topology building.

2.5.1 Feature Classes and Field Domains

A file geodatabase was created for storing the extracted vector data. Within the geodatabase separate feature classes were created for both polygons and linear features. These feature classes were named and used as a template to ensure consistency across all herds. The following naming convention was used: Template_disturbances_line for linear disturbances and Template_disturbances_polygon for polygonal disturbances.

The geodatabase and feature classes were created and managed using ESRI ArcCatalog software. The attribute fields listed below were included for each disturbance feature and managed by the geodatabase domain that defined a coded value for each attribute, where applicable to domain registration. The fields used were as follows:

FIELD Name	Description
HERD	Herd name
CLASS	Type of disturbance
LS_PATH	Landsat image path associated with feature's location.
LS_ROW	Landsat image row associated with feature's location.
LS_DATE	Date of Landsat imagery associated with feature's location.
INITIALS	Initials of digitizer
COMMENTS	Digitizers notes on feature
VERIFIED	Feature class has been confirmed with the aid of an ancillary vector dataset (Y/N)
VECTOR VERIFIED	If verified = Y: The dataset used to aid interpretation and classification of the feature.

The "Comments" field was the only field with a domain not defined. The "Herd," "Class," "Verified," and "Vector Verified" fields were controlled by a coded value domain. "Image path," "Image row," "Image date" (day, month, year) and "Initials" fields were controlled by range domain. Default domain values pertaining to the herd, interpreter, and image information were set prior to digitizing to increase time efficiency.

2.5.2 Coordinate System

The following coordinate system was used for all collected data:

Map Projection Name: Albers Conical Equal Area
Standard Parallel: 49.000000
Standard Parallel: 77.000000
Longitude of Central Meridian: –95.000000
Latitude of Projection Origin: 49.000000
False Easting: 0.000000
False Northing: 0.000000
Planar Coordinate Information
Planar Distance Units: metres
Coordinate Encoding Method: coordinate pair
Coordinate Representation
Abscissa Resolution: 0.000100
Ordinate Resolution: 0.000100
Geodetic Model
Horizontal Datum Name: North American Datum of 1983
Ellipsoid Name: Geodetic Reference System 80
Semi-major Axis: 6378137.000000
Denominator of Flattening Ratio: 298.257222

3.0 DISTURBANCE MAPPING METHODOLOGY

3.1 Landsat Image Selection

All Landsat imagery was selected to be between May and September in order to avoid the presence of snow or ice in the imagery. The process to identify and select the date for the imagery used to map the disturbance for each meta-herd was based on the year of collection for the demographic data for that specific meta-herd. In order to cover all local populations, update mapping, as well as new collections were mapped using the most recent Landsat imagery available (2008 to 2010 depending on cloud cover).

In order to match the Landsat imagery to the meta-herd's associated demographic data the following procedures were followed:

a. The World Reference System (WRS) catalogue index for Landsat was opened in ArcGIS and overlaid with the herd boundaries (Figure 25).
b. The Landsat path and row (tiles) that overlapped the herd to be mapped were selected (Figure 25).
c. The overlapping path and row information was used to query USGS EarthExplorer tool (U.S. Geological Survey), which in turn provided a list of archived Landsat images satisfying the query.
d. Images matching or closest to the herd's demographic sampling period for the herd being mapped were selected from the query output list and recorded for future use (Figure 27). The mapping period was defined as the earliest year listed in the herd sampling duration; this being

synonymous with the demographic data collection period (Table 24). For example, in the Pukaskwa herd the data collection dates were 1997, 1999 and 2001; therefore, Landsat images were selected to best match 1997. If the image for the mapping period date was not available under these criteria then the next closest available image year, preferably within the sampling duration, was selected. Because of limited available cloud free imagery, multiple image years can be used within a herd range for a single mapping period. Therefore, Landsat images with dates nearest to the year listed in the herd sampling duration were digitized first. For images within the same year of the sample period, the images with the latest date were selected first for digitizing.

e. The selected imagery was then downloaded from USGS site (as individual bands) and assembled as 3-band colour composites for the digitizing process.

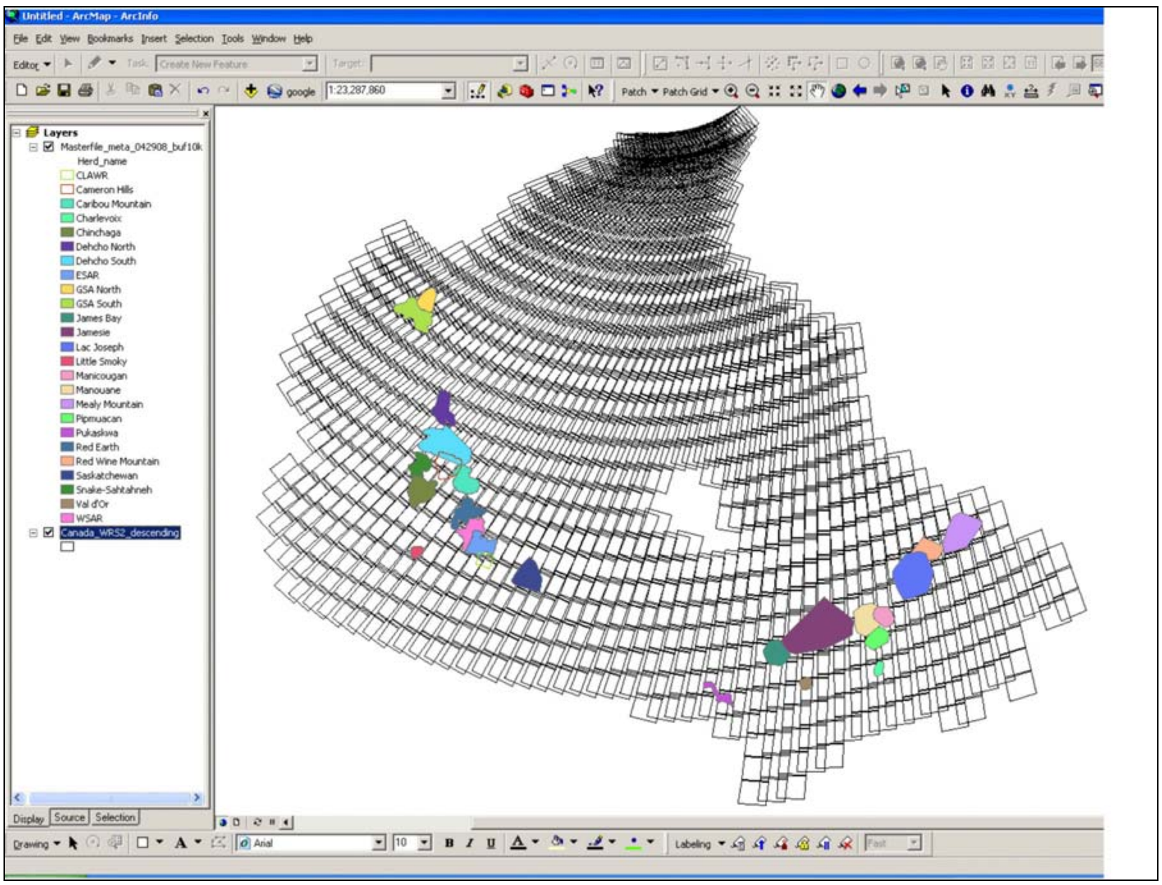


Figure 25. World Referencing System catalogue overlaid on project area during the image selection process with caribou herds visible.

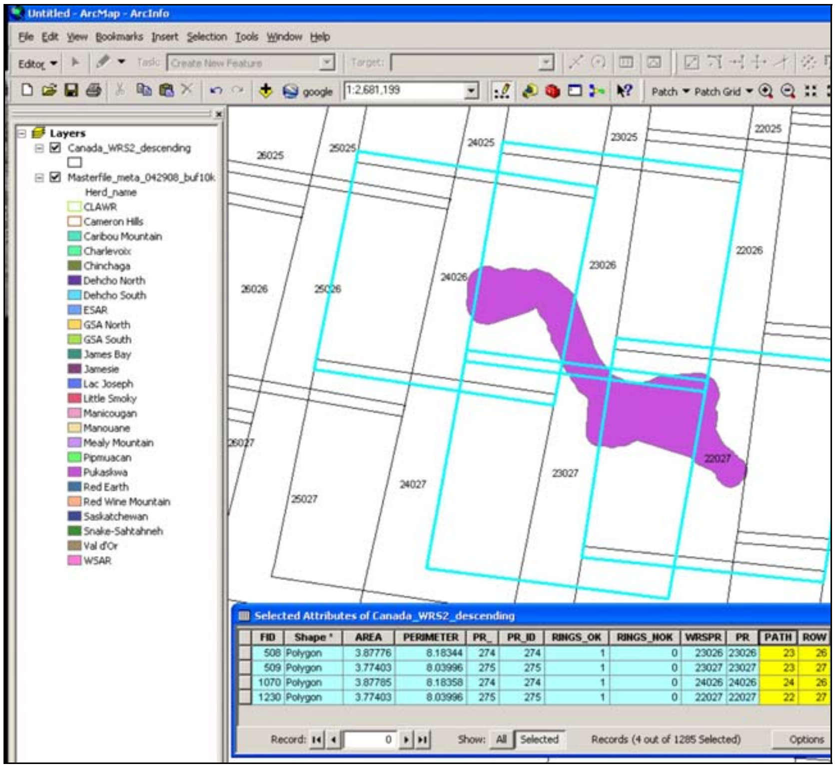


Figure 26. Landsat tiles overlapping the Pukaskwa herd range selected during the image selection process.

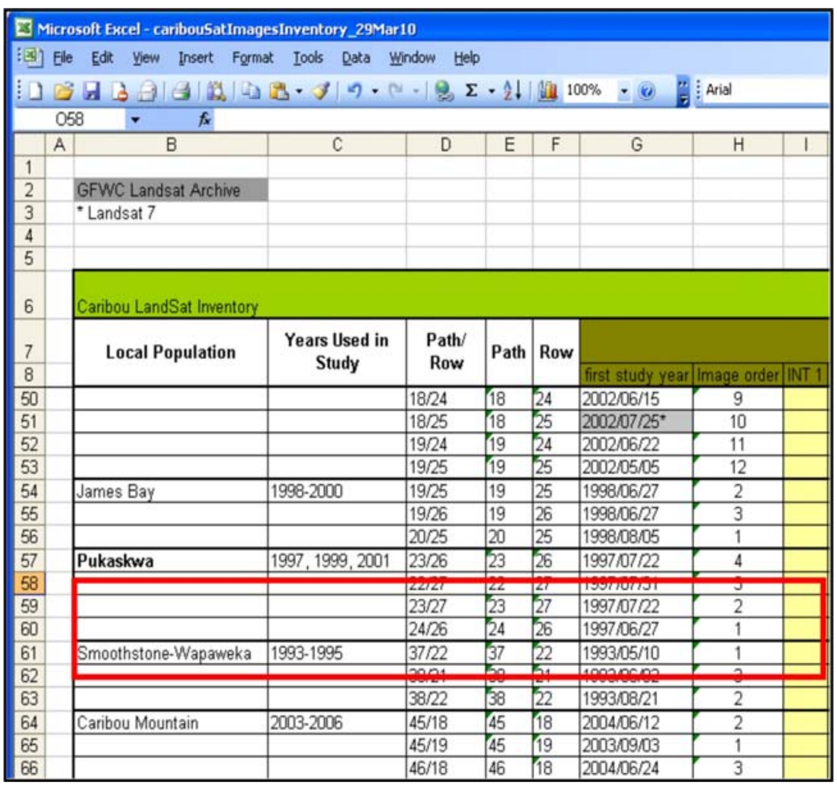


Figure 27. Spreadsheet used to log Landsat tiles associated with digitizing each herd.

3.2 Mapping Rules

In order to minimize inconsistencies and bias in the data collection between individual digitizers, the following mapping rules were established.

3.2.1 General Mapping Rules

1) Disturbances were mapped at a standard viewing scale of 1:50 000. This scale is adequate for accurately digitizing disturbances from medium resolution imagery. This scale is also consistent with previous mapping for GFWC's Canada Access dataset (GFWC, 2009) and intact forest landscape mapping.
2) Disturbances from both overlapping portions of Landsat tiles were not mapped unless it was necessary due to image quality or atmospheric interference (e.g. cloud or smoke cover).
3) For visual consistency across all areas, the band combination of 5, 4, and 3 with 2 standard deviation histogram stretch were used as the standard colour composition. This combination was used to delineate anthropogenic disturbance mainly due to the sensitivity of band 5 (mid-infrared) to vegetation moisture content. Alternate band combinations and image enhancements were used when required for digitizing accuracy or visual clarity (e.g. natural colour 3, 2, 1 with histogram equalization stretch or monochromatic band 5).
4) Disturbances were only mapped if visible on the Landsat image that was selected for the particular mapping period, even if disturbances that were not visible could be identified from ancillary data. The only exception to this rule was the GFWC reservoirs dataset (GFWC, 2009) which was directly copied into the disturbances dataset due to the very detailed dataset already in existence.
5) For each disturbance digitized, the interpreter was required to input a specified set of information into the attribute table.
6) Fires were considered as a natural disturbance process on the landscape regardless of their cause and were not mapped. If identifiable on the Landsat imagery, anthropogenic disturbances before or after the fire were mapped.

3.2.2 Rules Specific to Polygonal Disturbances

1) Polygon disturbances took precedence over linear features. In other words, with the exception of well sites (explained later on), linear anthropogenic disturbances were not mapped if they coincided with polygonal anthropogenic disturbances (e.g., roads within cutblocks).
2) In large disturbed areas, where there were fragments of the original landscape that remained as "islands" within the disturbed area, the decision to include or exclude an "island" fragment was governed by the size of the "island" fragment. To eliminate inconsistencies that would have arisen from the estimation of fragment sizes (on Landsat imagery) by different editors, a 500 m diameter circle was used as an aid to the inclusion or exclusion decision making process and used only in areas of uncertainty (Figure 28). Fragments approximately larger than this circle were left as undisturbed areas. It is also important to reiterate that the digitized disturbances will be buffered for further analysis, thus eliminating possible biases that may arise based on this criteria.

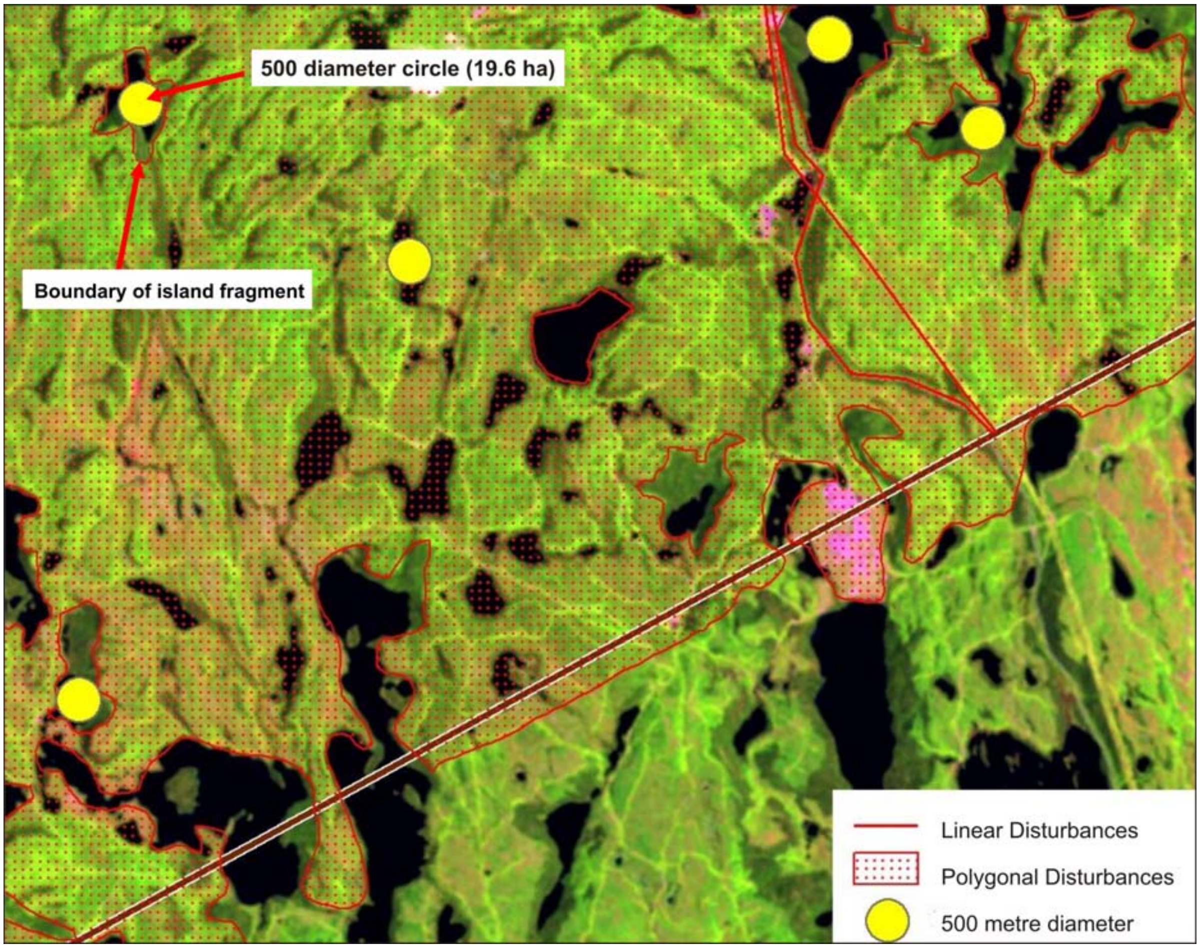


Figure 28. Highlighting the 500 m diameter/19.6 ha circle used to aid the identification of island fragments matching the >19 hectares criteria.

3) Well sites were identified from the imagery and ancillary vector data (IHS Energy, 2009). Sites were digitized as a point feature and buffered with 50 m radius circles that corresponded to the average size of a conventional petroleum and natural gas well site (CLMA and FPAC, 2007; SFM, 2001). As of June 2010, well sites were added as polygons with a radius of 50 m.
4) Due to their small size, high density in many locations and close association with pipeline and road networks, linear disturbances were digitized through well sites. The overlapping portion of the linear disturbance was later removed during post processing.

3.2.3 Rules Specific to Linear Disturbances

1) Where roads were adjacent to a second type of linear disturbance and the two could not be visually separated by the interpreter a single linear feature was digitized with roads taking precedence over other pipeline features. The secondary linear disturbance was only digitized as a separate vector when the two features split. For example, if a pipeline was parallel to a road and the distance separating the two features was not enough to allow visual separation on Landsat, (e.g. less than 90 m) the feature type was labelled as a road. Figure 29 shows an example of this situation.

2) For all other linear features, when multiple features were running parallel to each other they were digitized as separate features when visibly separated on the imagery. This rule was applied on an interpreter basis but generally the minimum separation between linear features was 3 pixels or approximately 100 m. When ancillary data showed more than one feature type present, the order of precedence was set as: roads, railways, powerlines, pipelines, seismic lines, and dams. Figure 30 shows an example of this situation.

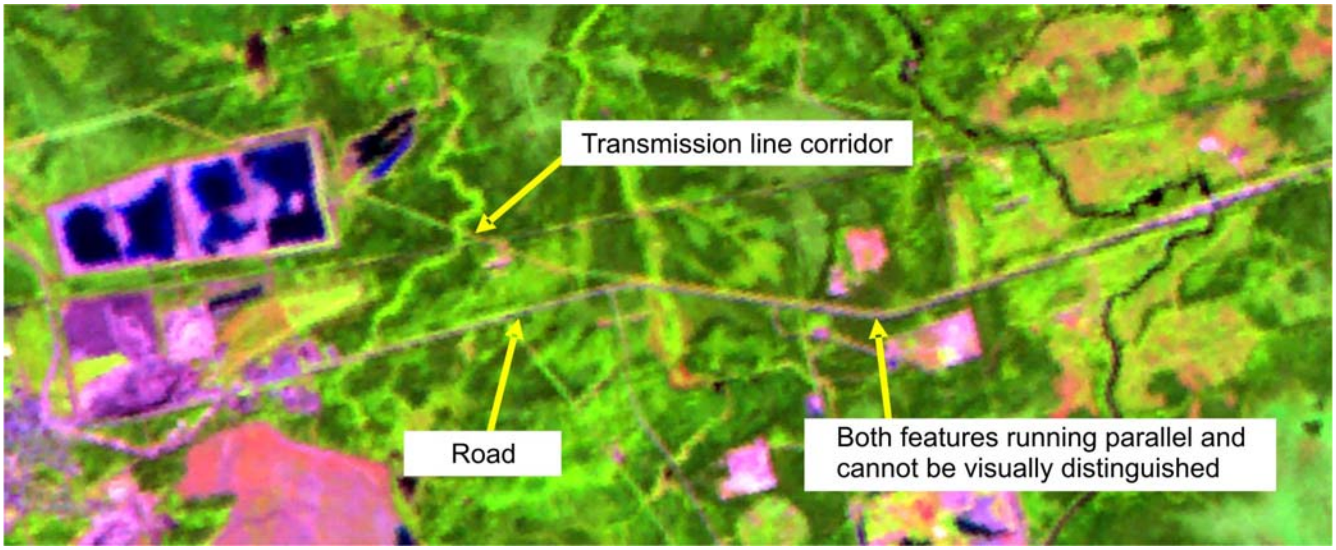


Figure 29. Linear disturbances converging making feature distinction difficult due to image resolution.

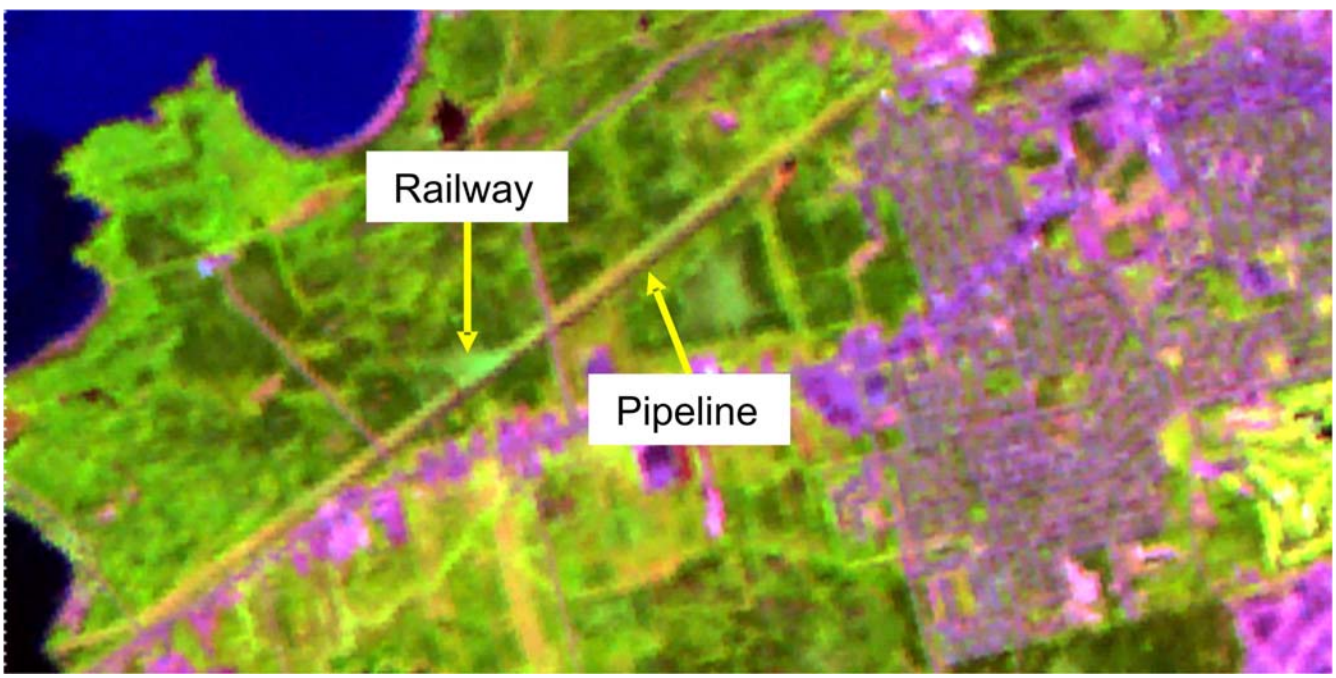


Figure 30. Linear disturbances running parallel and collected separately.

3.3 Data Collection

3.3.1 Setting Up a New Project

Create Feature Class: The feature class templates created at the database setup stage for storing linear and polygonal disturbances were copied and renamed to the herd being digitized. For example, if the Pukaskwa herd was being prepared for digitizing, the feature classes were renamed using the following naming conventions: Pukaskwa_disturbances_line_orig and Pukaskwa_disturbances_poly_orig.

Load Data in Digitizing Environment: The empty feature classes were opened in ArcGIS along with the herd boundary layer and the required reference system for the project was set. The images overlapping the herd to be digitized along with the ancillary data layers were then added to the ArcGIS project. The herd boundary was zoomed to the full layer extent of the ArcGIS window and the Landsat imagery radiometrically enhanced for interpretability. Relevant ancillary datasets were symbolized to enhance interpretation.

Snapping Tolerances: Snapping was enabled between vertices of polygonal and linear disturbance features to minimize or eliminate the occurrence of overshoots and undershoots. A snapping tolerance of 100 m was set based on test conducted at 1:50,000 to achieve necessary topological correctness.

1:50 000 Grid Layer: In order to help the digitizing process, a polygon grid layer covering all of Canada was initially generated with each grid cell being 17 km E-W x 10 km N-S. On standard monitors being used by the digitizers (resolution approximately 1680 x 1050), a single grid cell was visible at one time providing bounds to work within and a method to keep track of areas already mapped. Figure 31 shows an example of a set-up ArcGIS project with the 1:50 000 grid in place.

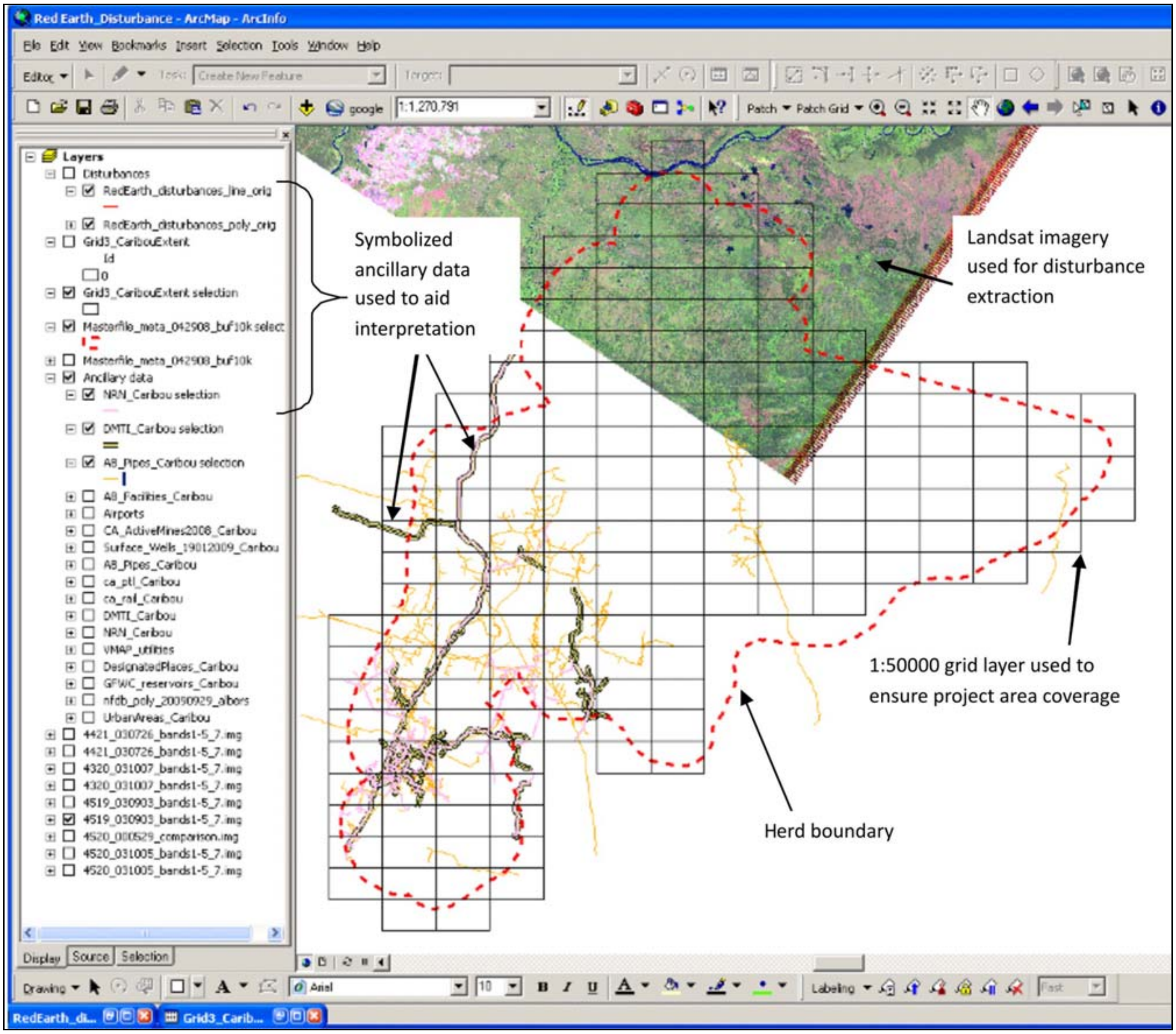


Figure 31. An example of the initial setup of a project ready to begin disturbance mapping.

3.3.2 Digitizing

Polygonal disturbances were digitized along their boundaries, while linear disturbances were digitized along their approximate centerline. A node was placed at the center of the starting and ending point of the linear feature. If the feature being digitized changed direction along its route, nodes were also placed at the locations of directional change as needed. In general, as a result of the resolution of the imagery (30 m) and the viewing scale used for digitizing (1:50 000), a certain degree of generalization was expected in the mapping. Small curves were represented as straight lines and smooth turns were angular in geometry.

Both point mode and stream mode were used for digitizing depending on the interpreters preference. Point mode (stationary) involved placing individual points or nodes along the lines or polygon edges with the individual interpreter deciding exactly where nodes would be, while stream mode (dynamic) recorded nodes continuously at an interval of 100 m as the individual interpreter moved along a line (Figure 32).

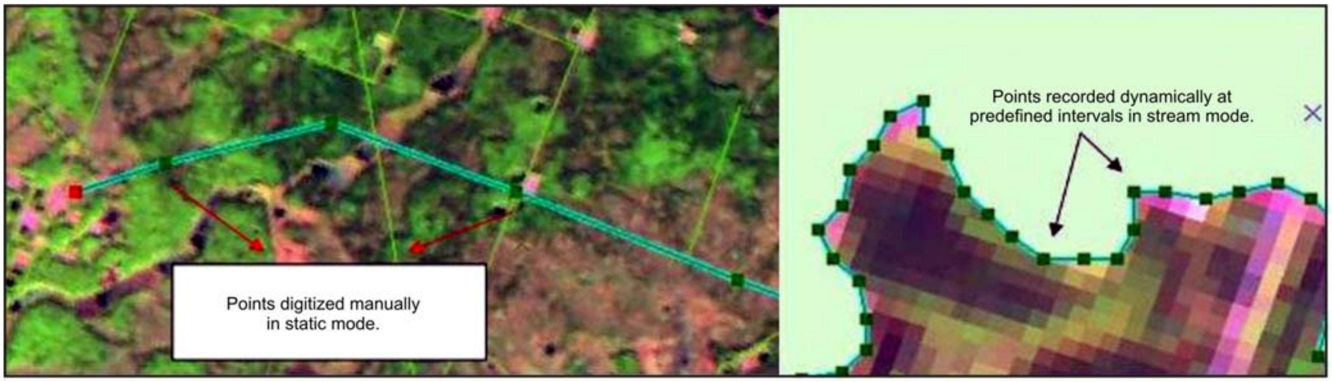


Figure 32. Point (left) and stream (right) modes digitizing.

Use of the 1:50 000 Grid: The 1:50 000 grid which provided a single grid cell on the screen when zoomed to 1:50 000 viewing scale was used to keep track of areas already checked and mapped. Features visible within this grid cell were mapped accordingly and interpreters moved along one cell at a time often marking (through symbology) which grid cells were completed and which remained. The entire area was systematically reviewed on a grid by grid basis using this process (Figure 33).

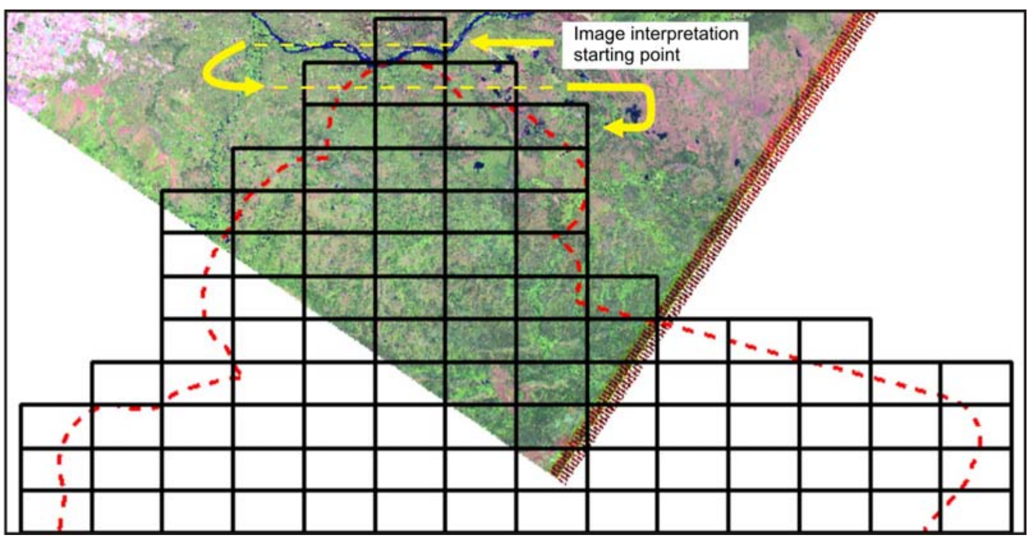


Figure 33. The use of a grid to systematically review and digitize disturbances within meta-herd areas and local population ranges.

3.4 Review of Collected Features and Completion of Digitizing Phase

At the end of the digitizing process for each herd, the interpreter reviewed the work done for obvious errors of omissions. The viewing scale was set to 1:100 000, which allowed four grid cells to be viewed on screen at once and the editor visually reviewed the area on screen for obvious omissions, making sure to set the scale to 1:50 000 for any additional digitizing.

3.5 Quality Control Methodology (QC)

Following full completion of the disturbance extraction for each region, the data were vetted through quality control (QC) to ensure adherence to the mapping rules and specifications. All QC was performed independently of the digitizing process by a qualified an individual who had not carried out any digitizing in the herd under review. When subsets were used, they were selected to be representative of the entire herd dataset. QC procedures involved a visual review and correction of non-conformances by the QC technician.

During the QC process the data was reviewed for:
1. Errors of omission: features wrongly omitted from the dataset.
2. Errors of commission: features wrongly included in the dataset.
3. Logical consistency: general consistency of the dataset.
4. Classification: correctness of feature attributes and classification.

The following steps were followed in order to carry out the QC procedure:

1) **Copied and renamed the disturbance layers** in order to keep separate the original data from the verified data, herein referred to as quality controlled data. The copied data was renamed for use in the QC process using the following naming convention: Pukaskwa_disturbances_line_QC and Pukaskwa_disturbances_poly_QC.

2) **All necessary data layers were added** to ArcGIS project, including herd boundary, disturbance layers, ancillary information, Landsat scenes and the 1:50 000 grid.

3) A **sample area was selected** based on the 1:50 000 grid layer used during the digitizing. In the case of updated mapping for the entire local populations using up-to-date Landsat imagery, the entire local population was examined by in the QC process. In the case of the original meta-herd mapping, in order to speed up the processing, only a sample area from each herd were examined. The sample area included an entire row or column of the 1:50 000 grid cells spanning the width or length of the herd. Whether a row or column was chosen depended on the orientation, density, and the variety of digitized disturbance types within the area (e.g., Figure 34).

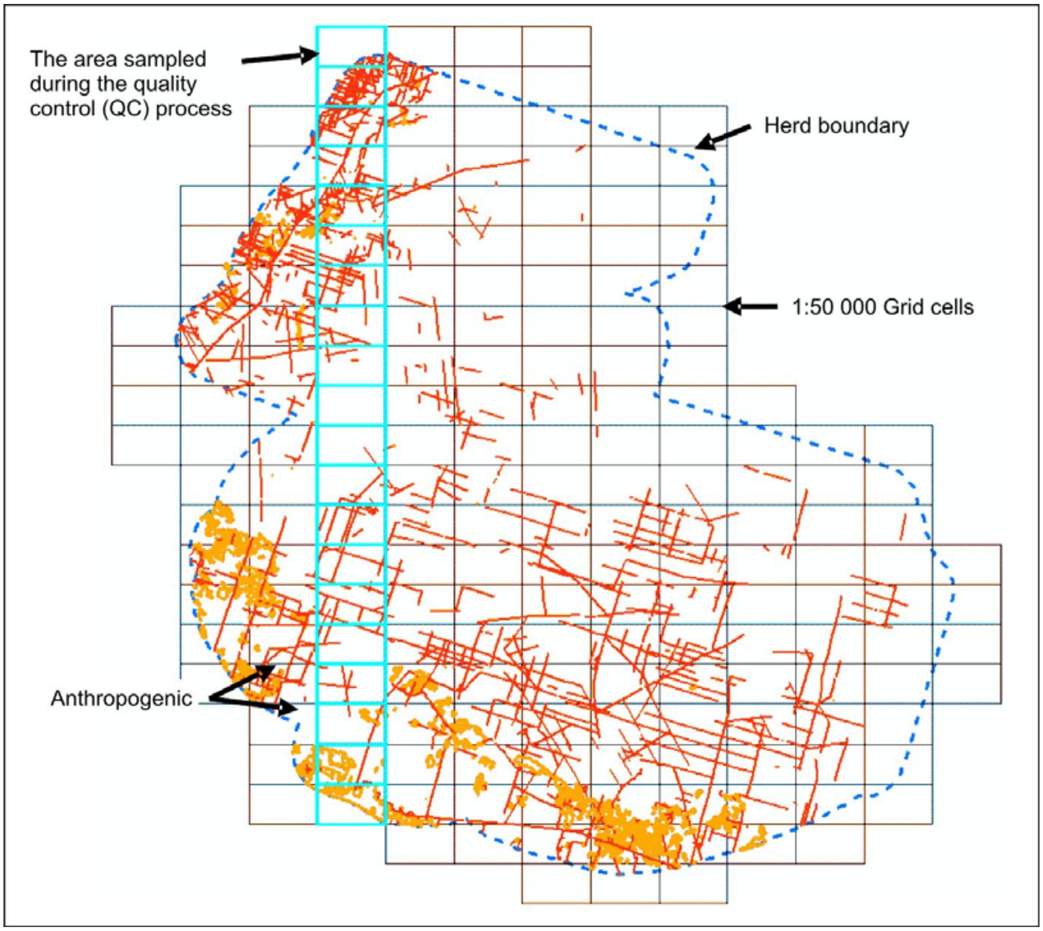


Figure 34. The sample area chosen and disturbance variety within the area. Linear disturbances are shown in orange, while polygonal disturbances are shown in red.

4) The **sample area was reviewed** at a viewing scale of 1:50 000 on a cell-by-cell basis. The viewing area was visually checked for errors of omission, commission or consistency by toggling the ancillary data and digitized disturbance layers on and off screen. Identified errors that were fixed or deleted were noted on a tracking sheet to be used when tabulating changes or fixes. Newly digitized features were also recorded. At the end of reviewing a grid cell, the QC technician panned to the next cell and continued the process described above.

5) Once the review of the sample area was completed the **QC edits were compiled and summarized** as a percent error of the total number of features. If the QC edits were greater or equal to 5% then this process was carried out for the entire herd (i.e. all 1:50 000 grid cells) before moving to the next step. If the QC edits were less than 5% the QC technician would then proceed to the next step.

6) The herd was finally **reviewed at a 1:100 000** viewing scale to check for any remaining errors.

7) The **attribute table was checked** for spelling errors, and the image path, row, day, month and year of the associated Landsat image used in the digitizing process were verified, in terms of feature classification.

3.6 Post Processing – Building Topology

Once the QC process was completed the data passed through a series of post processing steps that ensured topological consistency for use in further GIS analyses. Topology refers to the standardized rules that determine how feature lines and polygons share geometry within a GIS database. Predefined rules were set to guide the topological processing of the data. The processing steps followed are given below.

1) A **feature dataset was created** inside the file geodatabase and given the same projection as the feature classes.

2) The **line and polygon feature classes were saved into the feature dataset**. Files were named using the following naming structure: herdName_disturbances_line and herdName_disturbances_poly.

3) To reduce manual topology checking, **all multi-part features** (a polygon with multiple parts but only one record in the attribute table) **were converted to single parts**. This was accomplished by selecting all features (first line features and then polygon features) and using the "Explode" tool in the advanced editing toolbar (ESRI, 2009).

4) Any polygons accidentally created during interpretation that were **less than the minimum mapping unit of 2 ha** were removed, with the exception of well sites which are collected with the standard 50 m radius circular polygon.

5) **Check Geometry** was run since errors in geometry could cause the topological process to fail or produce erroneous results. Any results found were immediately corrected.

6) **If reservoirs existed**, there may have been some overlap with the digitized data and therefore using the "*Clip*" option in the "*Editor*" dropdown menu, the overlaps between the datasets were removed before the topology was built.

7) The **topology inside the feature dataset was created and all topological errors were corrected**. The topology contained both the line and polygon feature classes and was given a rank of 1, setting equal weight to each class. The following topological rules were used to correct topological errors:

   Topology Rule 1: **Lines must not intersect**.
   This error existed in two forms: point or polyline. Point errors were selected and automatically corrected by executing the "*Split*" command from the "*Error Inspector*" table. This divided the line feature into two separate features with the same attribute information. Polyline errors were corrected manually by zooming to the feature and subtracting one of the features that intersected. When all errors were corrected, the topology was updated by running the Validate Topology option.

   Topology Rule 2: **Lines must not overlap.**
   The same procedure was used as with "must not intersect". When finished the "*Validate Topology*" command was executed to update any corrections made.

Topology Rules 3: **Lines must not self-overlap.**
All errors were manually fixed and the topology was updated.

Topology Rule 4: **Lines must not self-intersect.**
All errors were manually fixed and the topology was updated.

Topology Rule 5: **Lines must be single part.**
All errors were manually fixed and the topology was updated.

Topology Rule 6: Polygons must not overlap.
Errors were checked and overlapping areas were merged into the appropriate polygon. In most cases the area of overlap was so small that it did not matter which polygon took precedence in merging. When finished, the topology was updated.

Topology Rule 7: Polygons must not have gaps.
This topology rule generated an error on the perimeter of the polygon if it was not part of a continuous surface. A method was developed to ignore or bypass the perimeter errors and fix the actual gaps or holes between or within polygons. All errors were selected and automatically fixed with the "*Create Feature*" option from the "*Error Inspector*" table. A new feature was created for every gap error. As a result, the features created from the perimeter errors were treated separately from the actual gap features.

First, new features (records with Null values for the "*Class*" field) that were larger than 3 hectares were selected and deleted. This allows us to ignore gap errors that are larger than 3 ha. The threshold was determined to be the area of a gap that could be attributed to interpreter error while gaps larger than this were likely created intentionally. This step eliminated many of the perimeter errors.

Other features that were less than 3 hectares were merged to their neighbouring feature with the longest shared border using the "*Eliminate*" tool. This resolved all gaps and unnecessary islands or donuts in the polygon dataset. The output was saved to the feature dataset created in step 1 and was named using the following naming structure: HerdName_disturbances_poly_Final.

The remaining new features (records with Null values for the "*Class*" field) that were not eliminated during the eliminate step were selected and deleted from the final polygon file to remove duplication.

At the end of this step, the polygon feature class within the associated "geodatabase topology" file was replaced with the final polygon file using ArcCatalog. Note that topology rule "Must not overlap" was applied to the final polygon file within the topology while the "Must not have gaps" rule was not added. The topology was validated before moving to step 8.

8) In order to **ensure that no lines overlapped polygons,** the "Erase" tool was run with the output saved to the feature dataset and renamed following this structure: Herdname_disturbances_line_Final.

When completed, the line feature class within the "geodatabase topology" file was replaced with the updated file using ArcCatalog and using the same topology rules applied previously. The topology was validated before moving on.

9) Since the dates were input as separate fields for day, month and year, they were merged into one field (LS_Date) using the YYYY/MM/DD standard.

10) All unnecessary files were deleted leaving only the following files:

The original files after 1st interpretation: HerdName_disturbances_line_orig and HerdName_disturbances_poly_orig.

The files following QC (second interpreter): HerdName_disturbances_line_QC and HerdName_disturbances_poly_QC.

The files after the final steps of post processing inside the feature dataset: HerdName_disturbances_line_Final and HerdName_disturbances_poly_Final.

4.0 UPDATED MAPPING FOR LOCAL POPULATIONS

As previously mentioned, while the original methods were developed for mapping disturbance within boreal caribou meta-herds, the methods were applied to carry out similar mapping within the caribou local populations with an interest in the most up to date disturbance information possible for the resource selection function and habitat modelling work. Mapping for the local populations used 2008 to 2010 Landsat imagery, with availability based on cloud cover. However, for some of the local populations in Labrador older imagery from 2006 and 2007 along with some Landsat 7 SLC off imagery (2009 and 2010) was required to fill in gaps as a result of extensive cloud cover in the Landsat 5 imagery over the desired time period.

The disturbance footprint for some local populations matched meta-herds identically, however many required completely new areas to be mapped. In the case of new areas, the exact method presented previously for disturbance collection were followed. Where existing mapping had already been done, copies of the original feature classes were made and loaded into ArcGIS. The interpreters added in additional features not seen or collected based on older Landsat imagery. Changes to existing disturbance type were kept to an absolute minimum. Only obvious major changes in type were applied, for example a change from a cutblock to a reservoir, not instances of pipeline to seismic (or visa versa). Since QC had already been completed for the original collection, only the updated features went through the QC process and instead of sampling the region as was done for the meta-herd QC process, the entire dataset was examined by the second interpreter. Finally, the entire feature dataset (original and updated combined) went through topology processing together.

4.1 Final Local Population Mapping Results

The end products of the disturbance mapping were used for various analyses throughout Phase 2 of the Boreal Caribou Critical Habitat Identification Project. Tables 29 and 30 provide a summary of the mapping efforts, presenting the length and area respectively for each local population broken down by mapped class.

Figures 35 and 36 provide cartographic examples of the mapping for western Canada populations where the landscape disturbance is dominated by oil and gas activity. Figures 37 and 38 provide similar examples, however from eastern Canada populations where the landscape disturbance is dominated by forest harvesting and the related road networks.

Table 29. Summary of the final polygonal disturbance mapping for each local population broken down into individual classes that were mapped.

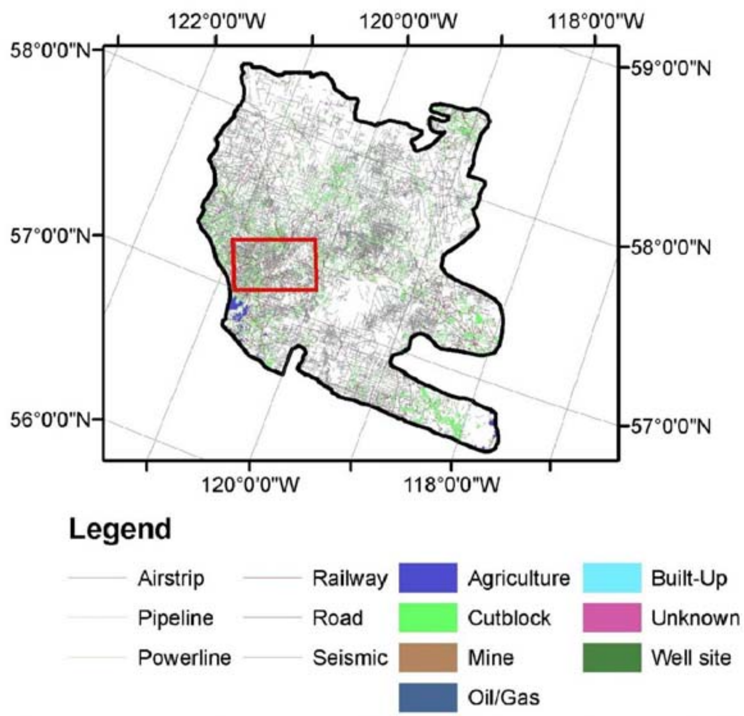
Range ID	Local Population	Agriculture (ha)	Built-Up (ha)	Cutblock (ha)	Mine (ha)	Oil and Gas (ha)	Reservoirs (ha)	Well Site (ha)	Unknown (ha)	Total (ha)
1	**Northwest Territories North**	0.0	1 266.9	484.5	166.5	271.4	0.0	115.4	9.8	2 314.4
2	**Northwest Territories South**	0.0	2 964.3	5 530.6	3 209.7	16.5	0.0	220.9	1 349.6	13 291.6
3	**Maxhamish**	0.0	16.5	7 905.9	0.0	213.3	0.0	283.5	17.1	8 436.4
4	**Calendar**	0.0	0.0	0.0	6.5	126.2	0.0	395.8	4.5	533.1
5	**Snake-Sahtahneh**	0.0	126.5	5 859.8	180.3	904.1	0.0	1 640.7	53.4	8 764.8
6	**Parker**	0.0	0.0	271.7	0.0	0.0	0.0	1.8	0.0	273.6
7	**Prophet**	0.0	0.0	1 729.2	0.0	0.0	0.0	20.4	0.0	1 749.6
8	**Chinchaga**	18 660.4	101.8	68 884.3	36.9	1 976.0	0.0	5 854.5	157.0	95 670.8
9	**Bistcho**	0.0	328.2	14 516.0	29.3	329.7	0.0	1 192.0	0.0	16 395.1
10	**Yates**	0.0	10.9	2 525.2	0.0	0.0	0.0	43.9	0.0	2 580.1
11	**Caribou Mountains**	588.1	3.7	26 984.6	0.0	0.0	0.0	46.3	81.4	27 704.1
12	**Little Smoky**	0.0	0.0	35 764.3	7.0	178.2	0.0	681.8	0.0	36 631.4
13	**Red Earth**	0.0	1 475.6	39 495.1	12.0	774.5	163.2	1 986.3	140.3	44 046.9
14	**WSAR**	0.0	284.4	16 421.1	2 032.0	0.0	0.0	2 746.0	0.0	21 483.5
15	**Richardson**	0.0	0.0	187.0	35.4	506.9	0.0	1 260.2	0.0	1 989.5
16	**ESAR**	2 561.2	226.1	36 539.4	100.9	4 231.3	0.0	3 841.1	146.5	47 646.4
17	**Cold Lake**	0.0	38.2	2 608.8	39.2	2 046.7	0.0	3 352.7	43.9	8 129.5
18	**Nipisi**	0.0	0.0	12 007.2	0.0	22.3	0.0	355.2	0.0	12 384.7
19	**Slave Lake**	0.0	0.0	4 441.3	758.7	623.8	0.0	384.4	0.0	6 208.1
20	**Davy-Athabasca**	0.0	213.4	30.7	411.2	0.0	0.0	0.0	185.2	840.5
21	**Clearwater**	0.0	245.1	292.7	46.1	62.4	0.0	256.8	55.4	958.6
22	**Primrose-Cold Lake**	3 174.8	2 206.9	80 888.8	1 738.5	0.0	0.0	175.9	413.0	88 597.9
23	**Highrock-Key**	0.0	414.0	68.1	2 002.9	0.0	0.0	0.0	453.0	2 938.0
24	**Smoothstone-Wapawekka**	3 715.9	5 572.0	272 525.2	324.4	0.0	69 046.0	0.0	926.6	352 110.1
25	**Steephill-Foster**	0.0	449.8	0.0	175.8	0.0	204 586.6	0.0	93.1	205 305.3
26	**Suggi-Amisk-Kississing**	546.6	2 346.5	37 594.5	1 814.1	0.0	9 409.7	0.0	2 270.6	53 982.1

Range ID	Local Population	Agriculture (ha)	Built-Up (ha)	Cutblock (ha)	Mine (ha)	Oil and Gas (ha)	Reservoirs (ha)	Well Site (ha)	Unknown (ha)	Total (ha)
27	**Pasqui-Bog**	38 869.1	618.5	64 507.2	915.4	5.9	0.0	2.4	0.0	104 918.5
28	**The Bog**	2 954.3	109.2	3 772.1	80.0	0.0	34 862.8	0.0	45.3	41 823.5
29	**Kississing**	0.0	6.6	12 992.4	0.0	0.0	0.0	0.0	0.0	12 999.1
30	**Naosap**	0.0	414.7	32 634.0	0.0	0.0	0.0	0.0	5.4	33 054.2
31	**Reed**	0.0	263.0	16 650.3	8.4	0.0	0.0	0.0	0.0	16 921.7
32	**North Interlake**	0.0	38.5	8 617.6	196.5	0.0	6 085.6	0.0	20.3	14 958.4
33	**William Lake**	0.0	61.1	10 976.9	0.0	0.0	0.0	0.0	311.3	11 349.3
34	**Wabowden**	0.0	305.6	22 885.3	33.4	0.0	0.0	0.0	98.3	23 322.6
35	**Wapisu**	0.0	413.7	8 744.5	1 048.7	17.4	291.1	0.0	25.7	10 541.1
36	**Manitoba**	45 528.7	12 568.0	111 461.4	8 148.4	0.0	271 722.9	0.0	1 520.3	450 949.7
37	**Atikaki-Berens**	0.0	527.2	1 853.5	10.8	0.0	0.0	0.0	0.0	2 391.6
38	**Owl-Flinstone**	0.0	43.9	9 737.7	0.0	0.0	0.0	0.0	0.0	9 781.6
39	**Sydney**	0.0	1 353.1	102 824.8	3 252.7	0.0	894.6	0.0	671.5	108 996.8
40	**Berens**	0.0	482.2	61 984.4	98.3	0.0	0.0	0.0	29.3	62 594.1
41	**Churchill**	0.0	553.4	216 600.1	158.2	0.0	0.0	0.0	240.7	217 552.3
42	**Brightsand**	0.0	341.4	283 585.9	195.4	0.0	0.0	0.0	54.4	284 177.1
43	**Nipigon**	0.0	2 180.5	380 895.5	54.6	0.0	0.0	0.0	534.6	383 665.1
44	**Coastal**	0.0	1 223.2	2 166.0	0.0	0.0	293.0	0.0	66.2	3 748.3
45	**Pagwachuan**	0.0	709.9	596 911.4	0.0	0.0	3 417.9	0.0	30.0	601 069.2
46	**Kesagami**	30 045.5	18 652.7	709 540.9	926.5	0.0	93 136.6	0.0	177.9	852 480.0
47	**Far North**	0.0	5 362.1	770.1	2 647.6	0.0	0.0	1.6	77.3	8 858.7
48	**Val d'Or**	4 662.0	3 957.9	52 888.3	3 682.0	0.0	9 051.8	0.0	321.9	74 563.9
49	**Charlevoix**	21.7	114.4	115 500.9	151.4	0.0	0.0	0.0	43.8	115 832.3
50	**Pipmuacan**	0.0	261.6	343 432.3	13.0	0.0	82 049.7	0.0	17.7	425 774.4
51	**Manouane**	0.0	1 024.5	326 300.2	13.0	0.0	76 723.6	0.0	271.3	404 332.5
52	**Manicouagan**	0.0	496.4	183 531.1	74.3	0.0	65 422.6	0.0	277.1	249 801.6
53	**Quebec**	5 593.2	9 224.3	2 777 359.8	38 188.8	24.6	1 666 891.5	0.0	877.9	4 498 160.1
54	**Lac Joseph**	0.0	77.5	6.0	6.8	0.0	2 383.5	0.0	95.5	2 569.3
55	**Red Wine Mountain**	0.0	2 866.9	25 707.5	1 054.9	0.0	261 855.7	0.0	242.9	291 727.9
56	**Mealy Mountain**	0.0	166.8	333.3	237.1	0.0	0.0	0.0	29.4	766.6
57	**Labrador**	0.0	854.4	235.5	13 200.3	0.0	44 821.2	0.0	73.5	59 184.8

Table 30. Summary of the final linear disturbance mapping for each local population broken down into individual classes that were mapped.

Range ID	Local Population	Airstrip (km)	Dam (km)	Pipeline (km)	Powerline (km)	Railway (km)	Road (km)	Seismic Line (km)	Unknown (km)	Total (km)
1	Northwest Territories North	7.9	0.0	45.6	0.0	0.0	1 386.7	8 090.0	0.0	9 530.2
2	Northwest Territories South	17.7	0.0	62.0	251.9	112.6	3 866.2	24 050.0	12.0	28 372.4
3	Maxhamish	2.1	0.0	201.6	0.0	0.0	660.0	4 986.6	0.0	5 850.4
4	Calendar	3.2	0.0	803.3	0.3	0.0	172.9	3 570.7	5.0	4 555.3
5	Snake-Sahtahneh	10.6	0.0	2 504.5	0.0	17.0	1 290.6	23 729.9	3.7	27 556.1
6	Parker	0.0	0.0	1.2	0.0	0.0	7.7	64.9	0.0	73.8
7	Prophet	0.0	0.0	16.2	35.2	0.0	139.1	1 126.4	0.0	1 316.9
8	Chinchaga	16.3	0.0	7 407.0	26.2	129.0	2 621.4	29 697.7	0.0	39 897.5
9	Bistcho	9.5	0.0	1 503.1	2.1	71.7	633.6	17 458.7	0.0	19 678.7
10	Yates	1.3	0.0	21.6	0.0	2.4	46.5	1 209.3	0.0	1 281.2
11	Caribou Mountains	2.1	0.0	4.9	0.0	0.0	314.9	3 886.8	0.0	4 208.8
12	Little Smoky	1.3	0.0	593.0	25.7	0.0	714.1	4 165.7	0.0	5 499.8
13	Red Earth	12.3	0.0	2 317.9	0.0	0.0	906.2	11 132.9	0.0	14 369.3
14	WSAR	16.8	0.0	3 092.7	131.2	0.0	737.3	10 428.3	0.0	14 406.3
15	Richardson	1.9	0.3	711.8	0.0	0.0	345.3	1 022.2	0.0	2 081.4
16	ESAR	5.4	0.0	3 679.1	77.8	34.7	717.0	10 637.0	0.0	15 151.0
17	Cold Lake	8.5	0.0	2 736.9	0.0	46.0	264.0	5 282.4	18.0	8 355.9
18	Nipisi	0.0	0.0	319.6	0.0	0.0	297.8	826.8	0.0	1 444.1
19	Slave Lake	0.0	0.0	369.4	14.4	31.8	435.0	308.6	0.0	1 159.1
20	Davy-Athabasca	6.9	0.0	0.0	92.9	0.0	336.8	110.9	10.3	557.8
21	Clearwater	5.0	0.0	236.2	53.0	0.0	988.2	52.9	0.0	1 335.3
22	Primrose-Cold Lake	1.3	0.0	147.3	86.0	0.0	2 733.3	1 706.4	14.1	4 688.5
23	Highrock-Key	7.0	0.5	0.0	277.3	0.0	1 515.2	65.0	28.6	1 893.6
24	Smoothstone-Wapawekka	5.5	0.0	0.0	71.4	0.0	4 156.6	99.9	0.0	4 333.3
25	Steephill-Foster	4.2	0.0	0.0	194.0	0.0	585.0	0.0	15.2	798.4
26	Suggi-Amisk-Kississing	4.4	0.0	0.0	124.7	0.6	1 045.2	0.0	2.6	1 177.5
27	Pasqui-Bog	0.0	0.0	12.9	0.0	62.9	661.9	12.7	0.0	750.4
28	The Bog	0.0	0.0	0.0	99.3	28.6	301.8	0.0	18.1	447.8
29	Kississing	0.0	0.0	0.0	18.2	0.0	87.1	2.3	0.0	107.6
30	Naosap	0.0	0.0	0.0	118.6	72.7	349.0	0.0	0.0	540.2
31	Reed	1.0	0.0	0.0	40.1	40.4	223.7	0.0	0.0	305.3

Range ID	Local Population	Airstrip (km)	Dam (km)	Pipeline (km)	Powerline (km)	Railway (km)	Road (km)	Seismic Line (km)	Unknown (km)	Total (km)
32	North Interlake	0.0	0.0	0.0	310.3	0.0	301.5	0.0	5.1	616.9
33	William Lake	0.0	0.0	0.0	141.9	0.0	340.8	0.0	35.0	517.7
34	Wabowden	0.0	0.0	0.0	226.3	76.5	439.9	0.0	9.6	752.3
35	Wapisu	0.0	0.0	70.8	87.3	24.9	337.2	34.1	0.0	554.3
36	Manitoba	4.3	0.0	0.0	1 740.9	428.6	6 031.4	8.9	45.7	8 259.8
37	Atikaki-Berens	1.9	0.0	0.0	184.0	0.0	711.9	5.1	0.0	903.0
38	Owl-Flinstone	1.5	0.0	0.0	70.1	0.0	392.5	0.0	0.0	464.1
39	Sydney	0.0	0.0	0.0	57.2	0.0	582.5	0.2	10.4	650.2
40	Berens	0.0	0.0	0.0	10.6	0.0	580.4	0.0	3.4	594.5
41	Churchill	1.2	0.0	0.0	193.0	34.7	1 491.4	0.0	1.2	1 721.5
42	Brightsand	1.7	0.0	0.0	0.0	146.5	1 108.7	0.0	1.6	1 258.6
43	Nipigon	2.9	0.9	0.0	39.8	277.6	2 585.2	10.7	7.9	2 925.0
45	Pagwachuan	0.0	0.0	0.0	182.4	102.7	396.4	0.0	0.0	681.5
46	Kesagami	0.0	0.0	0.0	60.9	79.8	2 505.4	31.9	9.4	2 687.4
47	Far North	2.0	0.0	0.0	447.5	255.0	4 572.1	207.3	1.7	5 485.7
48	Val d'Or	7.4	0.0	84.8	609.6	71.7	2 504.9	74.0	2.7	3 355.0
49	Charlevoix	0.0	0.3	4.8	92.0	42.3	933.3	0.0	2.5	1 075.1
50	Pipmuacan	0.0	0.0	0.0	86.9	0.0	789.2	0.0	0.0	876.1
51	Manouane	1.6	0.0	0.0	184.8	0.0	1 983.8	0.0	0.0	2 170.2
52	Manicouagan	0.0	0.1	0.0	0.0	0.0	1 272.6	0.0	1.9	1 274.6
53	Quebec	1.3	0.0	0.0	77.9	0.0	846.8	0.0	6.9	932.9
54	Lac Joseph	32.4	6.9	0.0	5 868.7	850.0	24 374.8	0.0	22.7	31 155.5
55	Red Wine Mountain	4.2	1.0	0.0	380.8	220.8	165.4	0.0	4.4	776.6
56	Mealy Mountain	1.7	0.0	0.0	308.8	0.0	959.4	14.8	0.0	1 284.6
57	Labrador	2.1	0.0	0.0	0.0	0.0	445.5	0.0	0.5	448.2
31	Reed	1.4	0.0	0.0	208.2	171.6	705.9	14.8	3.0	1 104.9



CHINCHAGA

Area of Local Population (ha) 3 162 612

Burned Area (1970-2010) (ha) 243 525

Anthropogenic Disturbance:

Polygonal (ha)		Linear (km)	
Agriculture	18 660.4	Airstrip	16.3
Built-Up	101.8	Dam	0.0
Cutblock	68 884.3	Pipeline	7 407.0
Mine	36.9	Powerline	26.2
Oil and Gas	1 976.0	Railway	129.0
Reservoirs	0.0	Road	2 621.4
Well Site	5 854.5	Seismic Line	29 697.7
Unknown	157.0	Unknown	0.0
Total (ha):	**95 670.8**	**Total (km):**	**39 897.5**

Number of Features Mapped

Polygonal		Linear	
Agriculture	29	Airstrip	21
Built-Up	9	Dam	0
Cutblock	869	Pipeline	9 110
Mine	9	Powerline	28
Oil and Gas	234	Railway	57
Reservoirs	0	Road	2 968
Well Site	7 455	Seismic Line	35 420
Unknown	28	Unknown	0
Total	**8 633**	**Total**	**47 604**

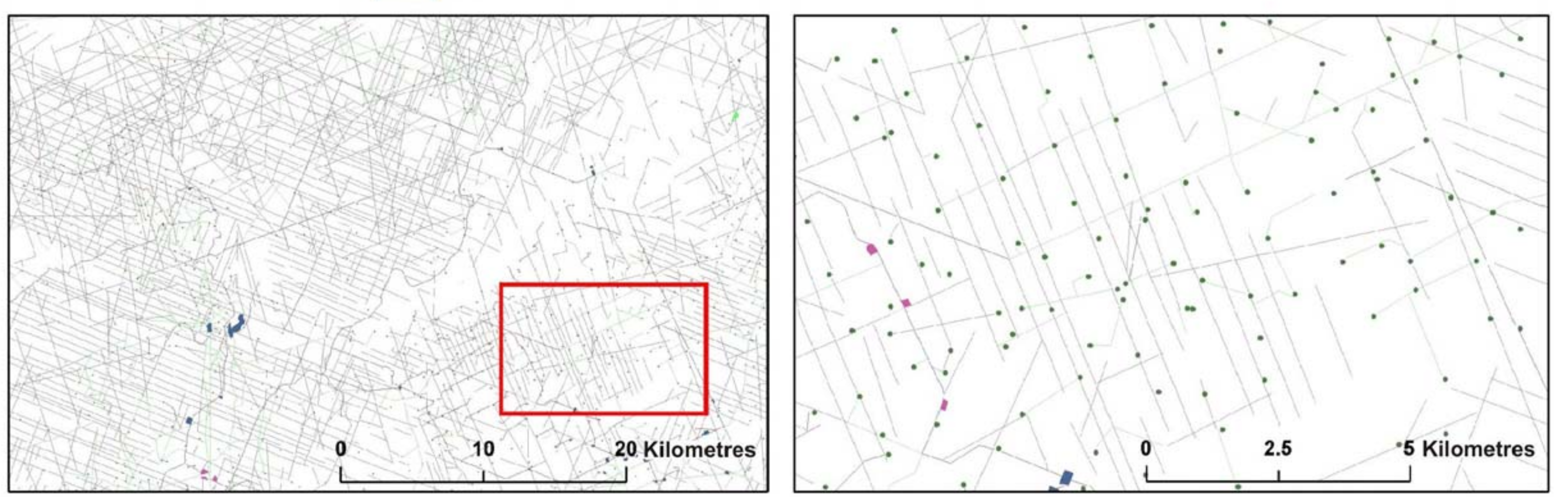
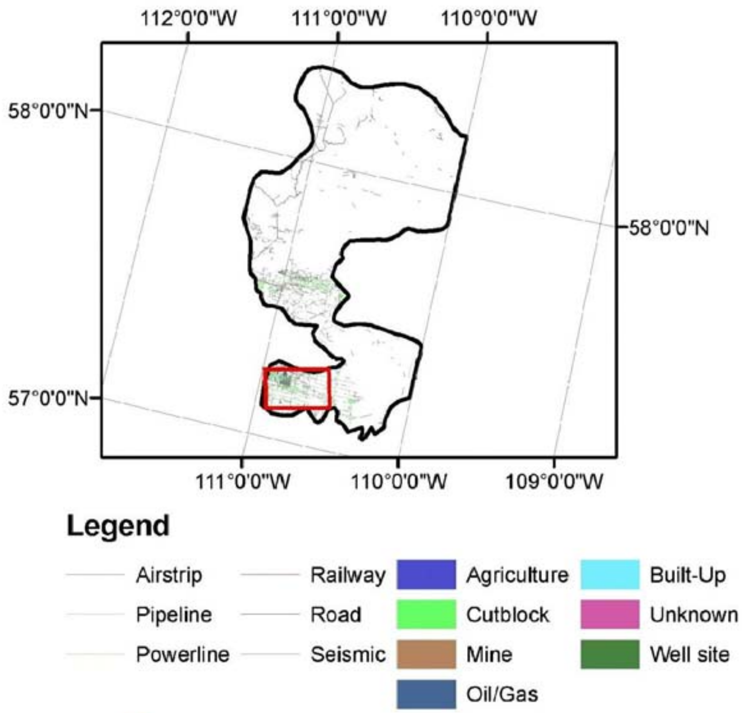


Figure 35. Final disturbance mapping for Chinchaga (B.C. and Alberta) local population. Two levels of insets are shown to demonstrate the mapping detail that was carried out. As well, the final statistics showing the area and length of features and the actual number of features broken down by class is shown.



RICHARDSON

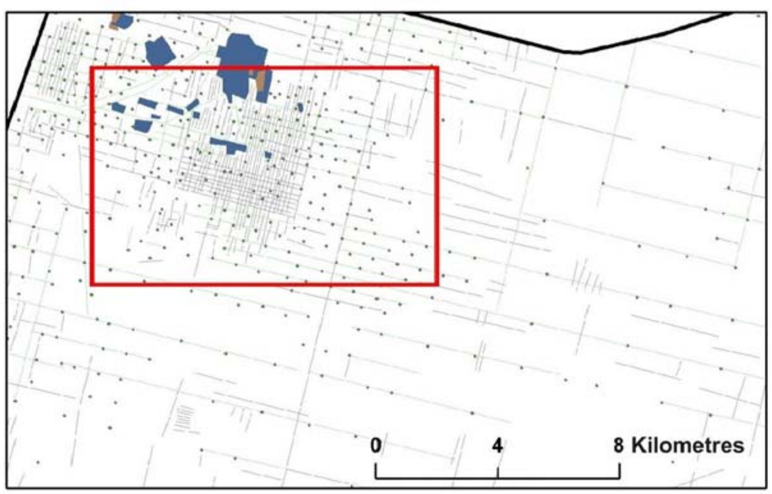
Area of Local Population (ha)	707 350
Burned Area (1970-2010) (ha)	472 901

Anthropogenic Disturbance:

Polygonal (ha)		Linear (km)	
Agriculture	0.0	Airstrip	1.9
Built-Up	0.0	Dam	0.3
Cutblock	187.0	Pipeline	711.8
Mine	35.4	Powerline	0.0
Oil and Gas	506.9	Railway	0.0
Reservoirs	0.0	Road	345.3
Well Site	1 260.2	Seismic Line	1 022.2
Unknown	0.0	Unknown	0.0
Total (ha):	**1 989.5**	**Total (km):**	**2 081.4**

Number of Features Mapped

Polygonal		Linear	
Agriculture	0	Airstrip	4
Built-Up	0	Dam	1
Cutblock	1	Pipeline	1 248
Mine	4	Powerline	0
Oil and Gas	17	Railway	0
Reservoirs	0	Road	157
Well Site	1 605	Seismic Line	2 065
Unknown	0	Unknown	0
Total	**1 627**	**Total**	**3 475**



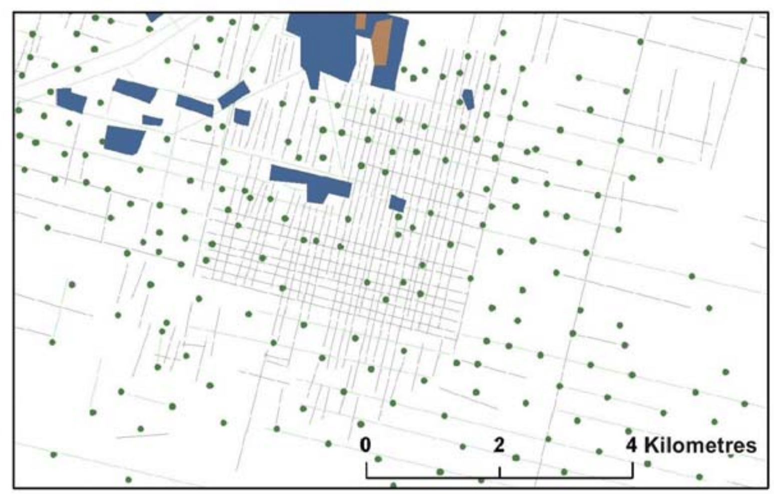
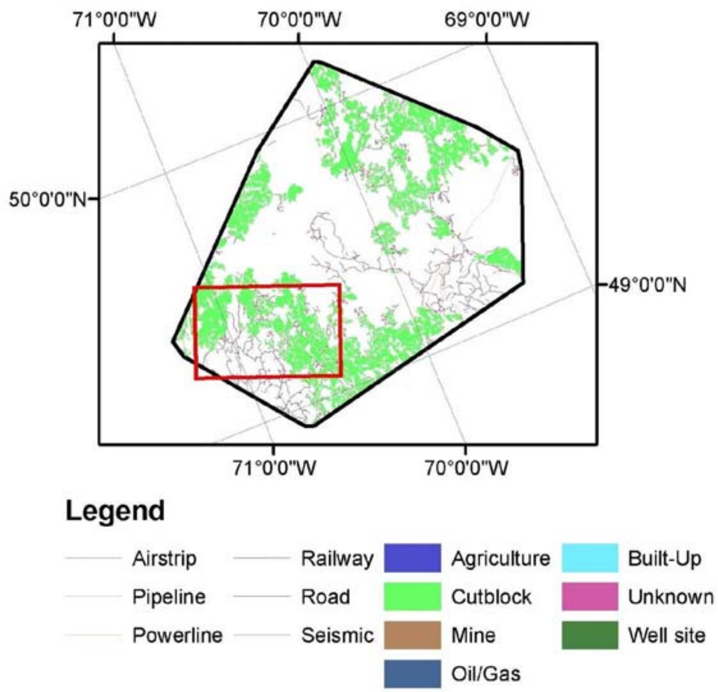


Figure 36. Final disturbance mapping for Richardson (Alberta) local population. Two levels of insets are shown to demonstrate the mapping detail that was carried out. As well, the final statistics showing the area and length of features and the actual number of features broken down by class is shown.



PIPMUACAN

Area of Local Population (ha)	1 376 899
Burned Area (1970-2010) (ha)	152 416

Anthropogenic Disturbance:

Polygonal (ha)		Linear (km)	
Agriculture	0.0	Airstrip	1.6
Built-Up	261.6	Dam	0.0
Cutblock	343 432.3	Pipeline	0.0
Mine	13.0	Powerline	184.8
Oil and Gas	0.0	Railway	0.0
Reservoirs	82 049.74	Road	1 983.8
Well Site	0.0	Seismic Line	0.0
Unknown	17.7	Unknown	0.0
Total (ha):	**425 774.4**	**Total (km):**	**2 170.2**

Number of Features Mapped

Polygonal		Linear	
Agriculture	0	Airstrip	1
Built-Up	0	Dam	0
Cutblock	839	Pipeline	0
Mine	3	Powerline	56
Oil and Gas	0	Railway	0
Reservoirs	3	Road	1 452
Well Site	0	Seismic Line	0
Unknown	2	Unknown	0
Total	**847**	**Total**	**1 509**

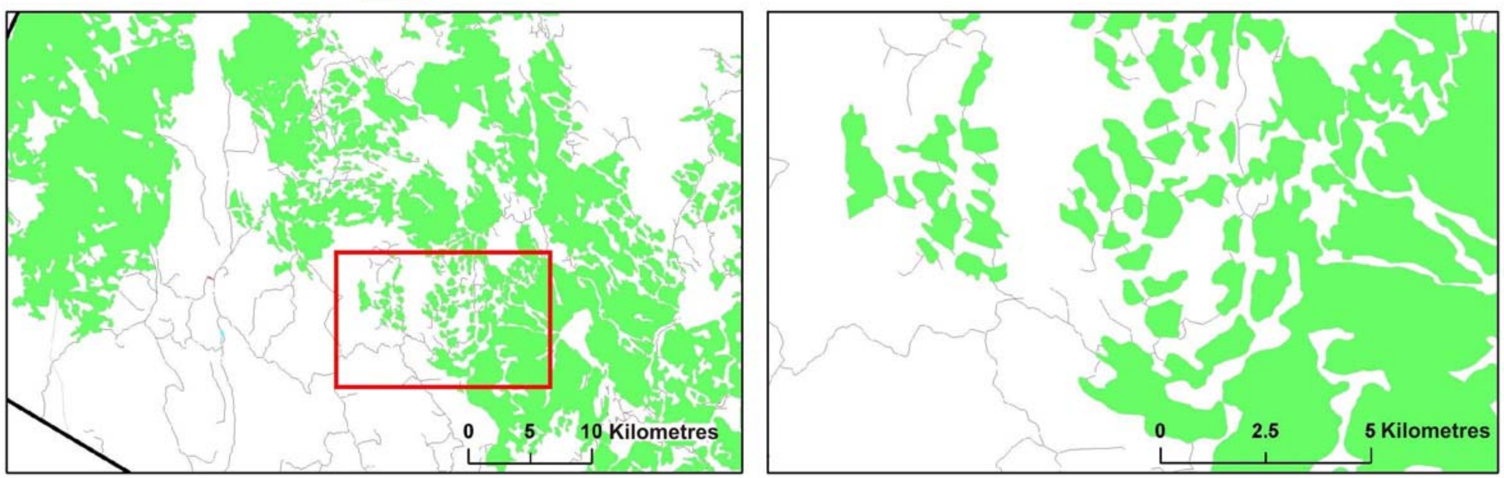
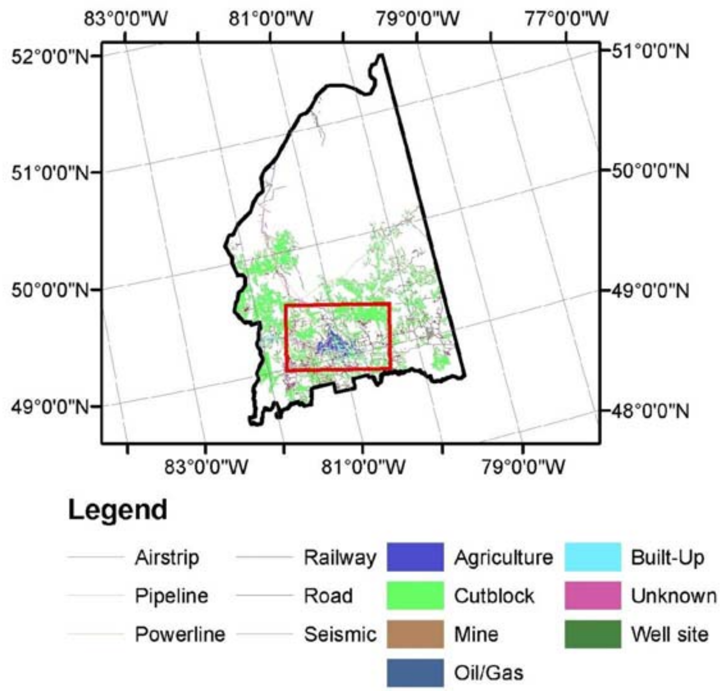


Figure 37. Final disturbance mapping for Pipmuacan (Quebec) local population. Two levels of insets are shown to demonstrate the mapping detail that was carried out. As well, the final statistics showing the area and length of features and the actual number of features broken down by class is shown.



KESAGAMI

Area of Local Population (ha)	4 766 463
Burned Area (1970-2010) (ha)	138 820

Anthropogenic Disturbance:

Polygonal (ha)		Linear (km)	
Agriculture	30 045.5	Airstrip	2.0
Built-Up	18 652.7	Dam	0.0
Cutblock	709 540.9	Pipeline	0.0
Mine	926.5	Powerline	447.5
Oil and Gas	0.0	Railway	255.0
Reservoirs	93 136.57	Road	4 572.1
Well Site	0.0	Seismic Line	207.3
Unknown	177.9	Unknown	1.7
Total (ha):	**852 480.0**	**Total (km):**	**5 485.7**

Number of Features Mapped

Polygonal		Linear	
Agriculture	74	Airstrip	1
Built-Up	394	Dam	0
Cutblock	1 671	Pipeline	0
Mine	12	Powerline	214
Oil and Gas	0	Railway	87
Reservoirs	17	Road	4,520
Well Site	0	Seismic Line	199
Unknown	6	Unknown	2
Total	**2 174**	**Total**	**5,023**

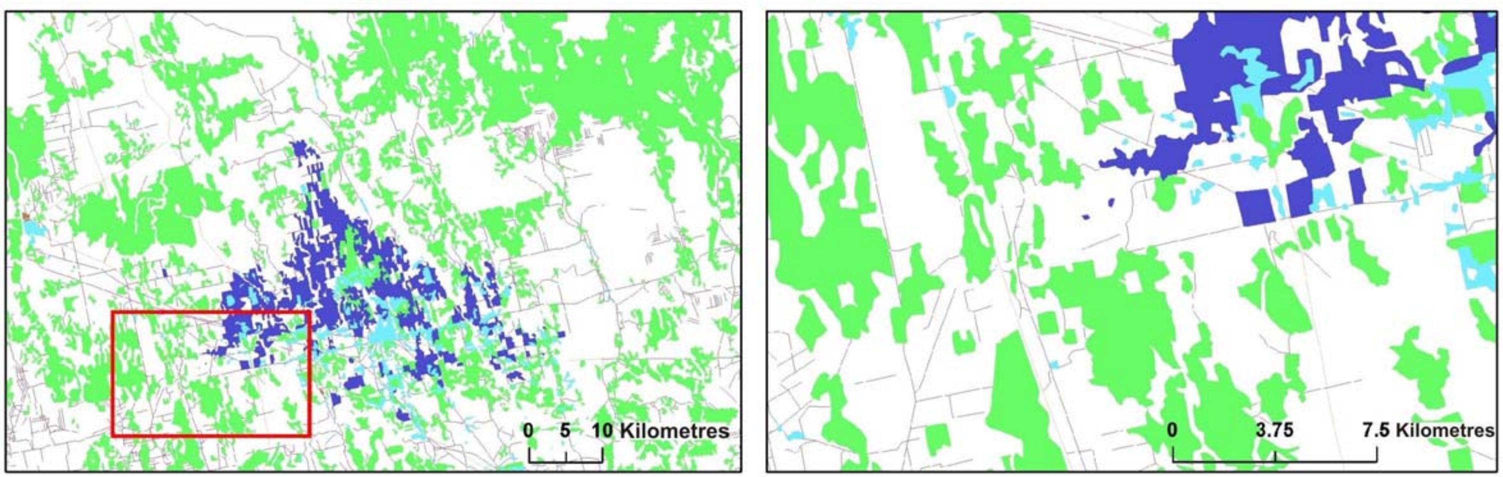


Figure 38. Final disturbance mapping for Kesagami (Ontario) local population. Two levels of insets are shown to demonstrate the mapping detail that was carried out. As well, the final statistics showing the area and length of features and the actual number of features broken down by class is shown.

4.2 Example of Quality Control Results

The quality control (QC) procedures carried out by a second interpreter who was completely impendent of the original collection for that specific area was an important step for ensuring completeness of the final disturbance mapping datasets. With such large areas and so many features collected, it was expected that the initial interpretation would have some errors that would be identified and corrected in the QC phase.

In presenting a few examples of the QC processes it must be kept in mind that the datasets produced by the QC process were later processed further to build topology. The final datasets, following topology, are not directly comparable to the original collections in terms of the number of features or total lengths or areas.

The same four local populations presented earlier were used to provide examples to show the value of the QC procedures. Tables 31, 32, 33 and 34 show comparisons between the original data collection and the data produced following the QC process. Many seismic lines and well sites were added to western Canadian regions, while in the east obviously roads and cutblocks were the dominant feature types that changed.

While the QC process did not, and nor was it intended to, provide measures of accuracy or ground truth, it was carried out to ensure the highest possible level of data collection completeness as well as the accuracy of feature classification.

Table 31. Pre and post-QC comparison for Chinchaga (Alberta / BC).

Linear Features	Original # of Objects	Original (km)	Final # of Objects	Final (km)	# of Objects Added	km Added / Remove
Airstrip	22	16.64	21	16.27	–1	–0.37
Pipeline	7060	6 751.90	7589	7 455.20	529	703.29
Powerline	23	26.17	23	26.17	0	0.00
Railway	50	129.00	50	129.00	0	0.00
Road	2033	2 761.16	2063	2 652.02	30	–109.14
Seismic	26512	27 684.85	28147	29 800.57	1635	2 115.72

Polygonal Features	Original # of Objects	Original (ha)	Final # of Objects	Final (ha)	# of Objects Added	ha Added / Removed
Agriculture	25	19 025.15	24	18 670.61	–1	–354.54
Built-Up	13	146.89	9	101.79	–4	–45.10
Cutblock	809	67 271.48	871	69 049.60	62	1 778.12
Oil & Gas	105	901.40	171	1 738.20	66	836.81
Reservoir	2	7.10	8	34.77	6	27.67
Well Sites	7258	6 012.13	7551	6 162.26	293	150.12
Unknown	61	477.35	28	156.98	–33	–320.37

Table 32. Pre and post-QC comparison for Richardson (Alberta).

Linear Features	Original # of Objects	Original (km)	Final # of Objects	Final (km)	# of Objects Added	km Added / Remove
Airstrip	2	1.92	2	1.92	0	0.00
Dam	0	0.00	1	0.27	1	0.27
Pipeline	287	719.17	305	750.46	18	31.29
Road	88	338.76	94	347.24	6	8.49
Seismic	783	996.74	809	1 036.90	26	40.16

Polygonal Features	Original # of Objects	Original (ha)	Final # of Objects	Final (ha)	# of Objects Added	ha Added / Removed
Built-Up	1	1.66	0	1.66	–1	0.00
Cutblocks	1	187.81	1	187.81	0	0.00
Mine	4	35.39	4	35.39	0	0.00
Oil & Gas	17	507.01	17	507.01	0	0.00
Well Sites	1586	1 245.64	1605	1 260.56	19	14.92

Table 33. Pre and post-QC comparison for Pipmuacan (Quebec).

Linear Features	Original # of Objects	Original (km)	Final # of Objects	Final (km)	# of Objects Added	km Added / Remove
Airstrip	1	1.62	1	1.62	0	0.00
Powerline	44	200.36	44	200.36	0	0.00
Road	1359	2 050.03	1530	2 367.63	171	317.61

Polygonal Features	Original # of Objects	Original (ha)	Final # of Objects	Final (ha)	# of Objects Added	ha Added / Removed
Built-Up	0	0.00	27	261.65	27	261.65
Cutblocks	781	339 754.21	801	344 801.02	20	5 046.81
Mine	6	16.91	6	16.91	0	0.00
Reservoir	4	160 247.64	4	160 221.75	0	–25.89
Unknown	13	190.27	3	18.86	–10	–171.41

Table 34. Pre and post-QC comparison for Kesagami (Ontario).

Linear Features	Original # of Objects	Original (km)	Final # of Objects	Final (km)	# of Objects Added	km Added / Remove
Airstrip	2	3.55	2	3.55	0	0.00
Powerline	88	498.44	100	515.04	12	16.60
Railway	38	252.29	53	305.21	15	52.92
Road	3061	5 064.98	3266	5 115.44	205	50.47
Seismic	8	13.96	145	208.42	137	194.46
Unknown	0	0.00	1	1.73	1	1.73

Polygonal Features	Original # of Objects	Original (ha)	Final # of Objects	Final (ha)	# of Objects Added	ha Added / Removed
Agriculture	74	33 208.16	72	30 252.80	–2	–2 955.35
Built-Up	394	18 224.28	396	18 759.33	2	535.05
Cutblocks	1638	748 460.76	1632	726 477.62	–6	–21 983.14
Mine	9	1 383.16	10	907.14	1	–476.02
Reservoir	10	93 173.77	11	93 196.89	1	23.12
Unknown	9	218.617	6	177.8655	–3	–40.7515

4.3 Quality Assessment of the Disturbance Decomposition Mapping Product

The purpose of this quality assessment was to quantify and categorize error in the disturbance mapping product including any variation and interpreter bias attributed to the manual digitizing process. Specifically, this assessment evaluated errors of omission and commission in both linear and polygon disturbance features for caribou herds in the western and eastern boreal forest. Quality assessment of the Landsat 30 m disturbance decomposition product was done via a comparison to higher spatial resolution GeoBase Orthoimage SPOT 4 and SPOT 5 imagery with a ground based pixel size of 10 m in the panchromatic band and 20 m for the multispectral bands. This evaluation did not use ground validation information.

GIS analysis were used to identify SPOT image tiles intersecting with herd boundaries and matched to within +/– 1 year of the Landsat image acquisition date used in the decomposition mapping. Due to limitations of available imagery this date was extended to within +/– 3 years of the disturbance mapping date for select herds in the eastern boreal.[1]

[1] Note that when scene dates were mismatched by greater than 1 year particular attention was given to correct the error assessment for any land cover change occurring between image dates by removing these features from the assessment. In these situations, a feature was deleted from the assessment when an obvious land cover change occurred and could not be attributed to interpreter error. For example, if a new cutblock appeared in SPOT imagery acquired 3 years after the Landsat imagery this feature was deleted from the assessment.

From this analysis, a subset of 13 herds, 9 in the western boreal and 4 in the east were identified for quality assessment (QA) and grid with a 5 km x 5 km mesh. A random sample of 2% of these grid cell locations was subsequently generated separately for each of the QA herds. Each 25 km^2 grid cell selected in the process was then flagged for use as a sample location in the quality assessment. In total, the area sampled represented approximately 7500 km^2 of boreal forest spatially dispersed over a range of disturbance conditions, landscape type and image quality.

A total of four individual interpreters with at least 6 months of experience in disturbance mapping took part in the quality assessment, each digitizing all randomly sampled QA cells in the SPOT 4/5 scenes. Interpreters followed the same protocol, i.e. rule sets, interpretation guidelines and feature class labelling as developed for the Landsat disturbance mapping. On completion, results were tallied and rolled up to the herd level. Mapping estimates amongst interpreters were used to evaluate individual biases based on the length, area and frequency of class type for linear and polygon features. Results of this assessment were summarized for linear and polygon features for all QA herds.

4.3.1 Linear Features

In most of the assessed herds in both the eastern and western boreal it was the linear features such as seismic, pipeline and roads where the errors of omission occurred, i.e. errors of omission are features visible and digitized in SPOT but not Landsat imagery. In particular, the resolution of the Landsat imagery limited detection and mapping of more recent seismic lines less than 10 m in width. Overall the average rate of omission by length for linear features in the Landsat disturbance product was approximately 62% with no difference between the eastern and western boreal (Table 35). Mapping of linear features was resolution limited with the 30 m Landsat imagery so these differences were expected. Errors of commission were minor.

Table 35. Interpreter variation in the length (km) of linear features mapped in GeoBase SPOT 4/5 imagery versus Landsat for all QA herds.

ID		Interpreter				Average (km^2)	COV (%)	Landsat (km^2)
		1	2	3	4			
East	Berens River	76.4	90.8	101.7	91.3	90.1	10.0	47.9
East	Pipmuacan	89.0	76.1	80.3	91.3	84.2	7.4	78.8
East	Valdor	221.3	204.0	213.8	201.1	210.1	3.8	111.3
East	Cochrane	64.2	66.8	68.2	69.1	67.1	2.7	43.7
West	Cameron Hills	1987.1	1754.5	1558.9	2196.8	1874.3	12.8	1142.9
West	Caribou Mountain	167.7	150.4	156.4	165.9	160.1	4.4	62.5
West	Chinchaga	1862.8	1673.4	1660.6	2048.4	1811.3	8.8	1092.2
West	Decho N	269.1	188.7	269.0	237.1	241.0	13.6	187.4
West	Decho S	522.5	424.4	530.5	497.5	493.7	8.5	206.3
West	GSA NS	218.6	135.7	200.1	159.2	178.4	18.3	78.4
West	Little Smoky	426.0	411.2	385.9	477.8	425.2	7.9	257.3
West	Snake Sahtaneh	1481.9	1217.6	1358.7	1580.6	1409.7	9.6	1039.8
	Total (km^2)	7386.8	6393.6	6584.2	7816.1	7045.2	n/a	4348.5
	Difference (km^2)	341.6	-651.6	-461.0	771.0	n/a	n/a	-2696.6
	Difference (%)	4.8	-9.2	-6.5	10.9	n/a	n/a	**-61.7**

Note: GSA north and south are aggregated.

Among the individual interpreters the range of variation was approximately +/–10% with again no differences between the eastern and western boreal. This variation represents individual interpreter bias. Most of the variation amongst interpreters could be attributed to an individual's ability to distinguish linear features on the landscape or choice of background colour composite, e.g. natural colour versus false colour infrared. Table 36 also confirms interpreter bias via the frequency of linear features mapped. There were obvious patterns with individual interpreters in both labelling the feature class and detection of the disturbance. On a herd basis individual bias was again evident in Figure 39. For example, there was a positive bias in the length of features mapped by interpreters 1 and 4 and this held true for all herds, being most pronounced in herds with a high density of linear features such as Cameron Hills, Chinchaga and Snake-Sahtahneh (Figure 40).

Table 36. Interpreter variation in the frequency of linear features mapped by class type in GeoBase SPOT 4/5 imagery for all QA herds.

Class Type	Interpreter				Average (No.)	COV (%)
	1	2	3	4		
airstrip	1	5	2	4	3	52.7
dam	0	2	0	0	1	173.2
pipeline	565	550	540	472	532	6.7
powerline	48	28	39	32	37	20.7
railway	7	9	8	12	9	20.8
road	995	891	944	1143	993	9.5
seismic	4025	3581	3262	4043	3728	8.8
unknown	10	1	1	9	5	81.2
Total	5651	5067	4796	5715	5307	n/a
Difference (No.)	344	-240	-511	408	n/a	n/a
Difference (%)	6.5	-4.5	-9.6	7.7	n/a	n/a

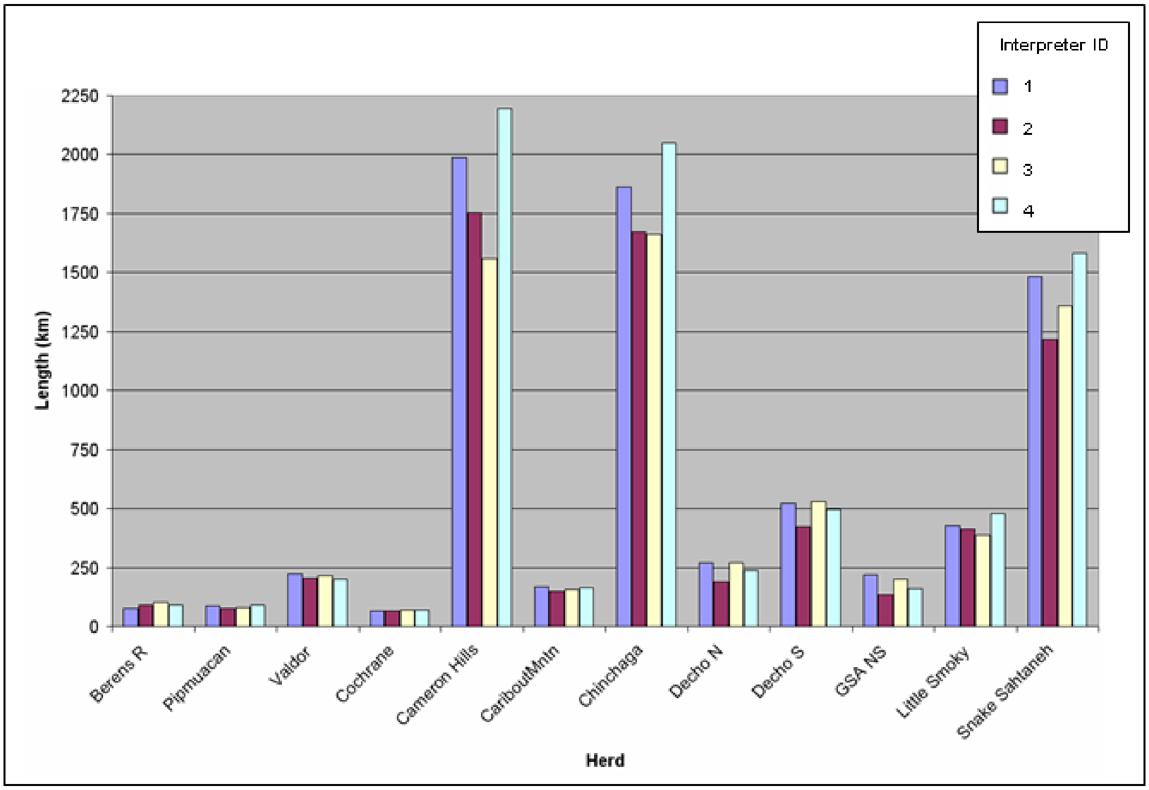


Figure 39. Interpreter variation in the of length (km) of linear features mapped with GeoBase SPOT 4/5 imagery for all QA herds.

These biases were however consistent across all herds for each interpreter meaning on a day-to-day basis individual interpreters were making consistent decisions in both digitizing a linear feature and in typing that feature. In areas with minimal or poor ancillary data assigning a class type label to linear features was often difficult given the ambiguous nature of linear features particularly in landscapes where multiple linear disturbances overlap as in the western boreal. In the eastern boreal there were fewer linear features, most of which were roads adjacent to cutblocks. As such, class type was generally more reliable in the eastern versus western boreal despite both have similar overall rates of omission.

4.3.2 Polygon Features

Most of the approximately 8% average overestimation of polygon area (Table 37) in the Landsat product was attributed to generalization of polygon boundaries when mapping with a 30 m ground pixel size versus higher resolution SPOT imagery. Errors of commission were generally minor for the herds assessed, i.e. very few features were detected and mapped on the Landsat but not on the SPOT imagery. As well, unlike linear features, the omission error for those polygon features mapped on SPOT but not on Landsat was low at less than 1%. Because the detection of polygon disturbance was less effected by resolution limitations the Landsat imagery was quite reliable in detecting polygon disturbance features greater than the 2 ha minimum mapping unit.

Table 37. Interpreter variation in the area (km^2) of polygon features mapped in GeoBase SPOT 4/5 imagery versus Landsat for all QA herds.

	ID	Interpreter 1	Interpreter 2	Interpreter 3	Interpreter 4	Average (km^2)	COV (%)	Landsat (km^2)
East	Berens River	38.2	36.6	44.2	36.7	38.9	8.0	43.3
East	Pipmuacan	32.5	32.4	36.0	30.5	32.8	6.1	31.3
East	Valdor	48.7	49.5	50.9	50.6	49.9	1.8	60.1
East	Cochrane	57.5	59.4	59.5	55.4	58.0	2.9	65.8
West	Cameron Hills	10.4	10.7	14.5	10.5	11.5	14.9	12.9
West	Caribou Mountain	0.9	0.8	0.0	0.9	0.7	57.1	1.0
West	Chinchaga	16.5	18.8	20.1	15.7	17.8	10.0	18.2
West	Decho N	0.1	0.0	0.1	0.1	0.0	37.1	0.1
West	Decho S	0.1	0.1	1.1	0.1	0.4	121.4	0.1
West	GSA NS	0.5	0.4	0.4	0.3	0.4	16.5	0.4
West	Little Smoky	40.7	41.3	43.4	37.8	40.8	4.9	38.9
West	Snake Sahtaneh	11.6	9.8	12.2	9.6	10.8	10.4	11.7
	Total (km^2)	257.6	259.9	282.4	248.1	262.0	n/a	283.8
	Difference (km^2)	-4.4	-2.1	20.4	-13.9	n/a	n/a	21.8
	Difference (%)	-1.7	-0.8	7.8	-5.3	n/a	n/a	**108.3**

Note: GSA north and south are aggregated.

In contrast, polygon boundary delineation was limited by image resolution for all QA herds and thus produced a positive bias in the area of polygons mapped. While the boundary delineation effect was present in all herds, there was a trend toward greater overestimation of polygon area in the eastern boreal versus the west. The may have been a result of different cutblock patterns particular to jurisdictions in the east or possibly errors of commission where wetlands were in fact mapped as cutblocks in the Landsat imagery. This trend requires further investigation.

In terms of interpreter variation, differences in the area of polygon features mapped by the individuals ranged by approximately +/–8% (Table 37) with interpreters 2 and 3 tending to map between 3 to 6% fewer polygons than interpreters 1 and 4 (Table 38). It was interesting to note the same two interpreters tended to map more area in polygons for several herds including Kesagami, Chinchaga, and Little Smoky. In particular interpreter 3 most often mapped more area in polygons but had the fewest number of polygons with this being most pronounced in Berens River (Figure 40). These differences were consistent across all herds and simply reflect individual interpreter bias. Again, as with linear features most interpreters were consistent in their interpretation calls for polygon features, meaning their results were repeatable with certain operator biases existing. For example, in Figure 39 the pattern of a positive bias in mapping polygon area was consistently evident with interpreter 3 and to some extent interpreter 2.

Table 38. Interpreter variation in the frequency of polygon features mapped by class type in GeoBase SPOT 4/5 imagery for all QA herds.

Class Type	Interpreter 1	Interpreter 2	Interpreter 3	Interpreter 4	Average (No.)	COV (%)
cutblock	532	398	420	577	482	15.5
settlement	77	29	88	35	57	44.8
agriculture	4	3	3	3	3	13.3
mine	98	129	74	165	117	29.3
oil/gas	37	55	98	21	53	54.5
reservoir	13	11	16	14	14	13.4
unknown	13	9	17	3	11	49.3
wellsite	456	506	382	432	444	10.1
Total	1230	1140	1098	1250	1179	n/a
Difference (No.)	51	-40	-82	71	n/a	n/a
Difference (%)	4.3	-3.3	-6.9	6.0	n/a	n/a

Assigning the class type for linear features was inherently more difficult than polygon features; however, there were still discrepancies amongst the interpreters when labelling polygon features (Table 38). For example, the relatively high COV% amongst interpreters for the cutblock, mine and oil and gas feature class types was an indication of confusion on the part of interpreters in choosing a class label. In many areas disturbance features were detected but there was insufficient evidence through context or pattern to assign a class type. This was particularly apparent in landscapes with multiple disturbances or areas lacking ancillary data.

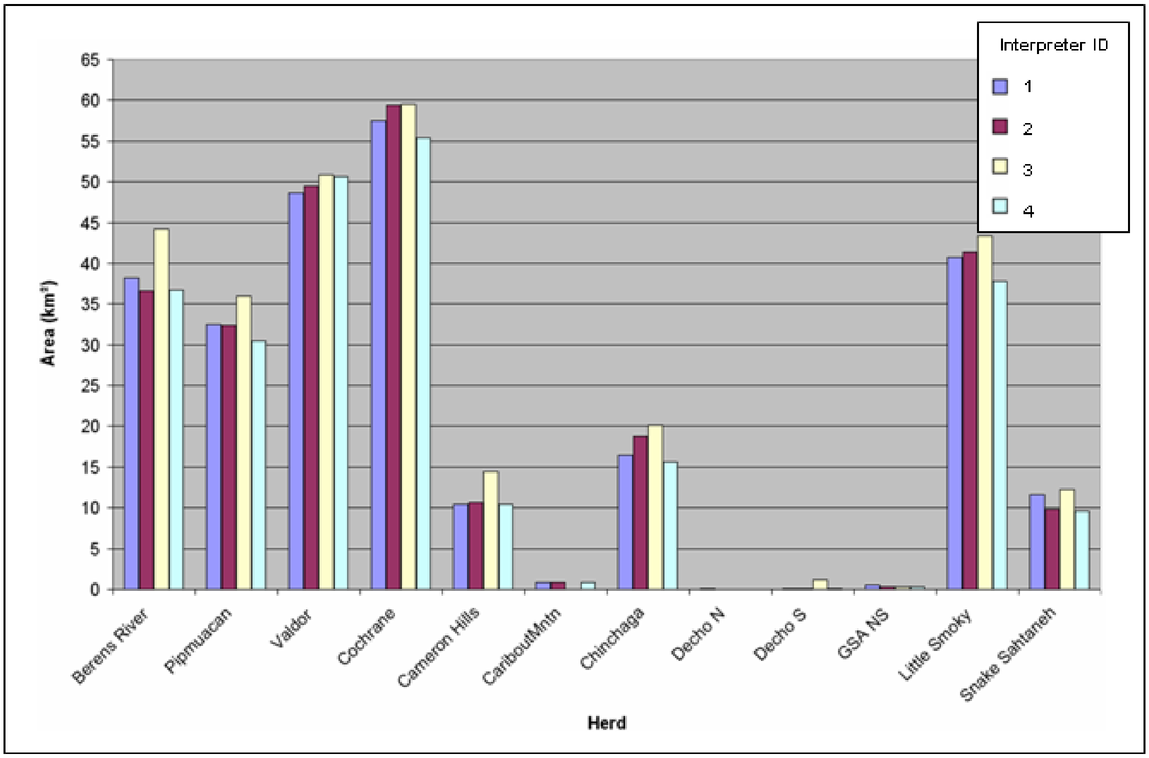


Figure 40. Interpreter variation in the area (km^2) of polygon features mapped with GeoBase SPOT 4/5 imagery for all QA herds.

4.3.3 Conclusions of Quality Assessment

1. On average there was a 62% underestimation of linear features by length in the Landsat based disturbance mapping product when compared to SPOT 4/5 imagery. Interpreter bias associated with mapping linear features was approximately +/–10% of this estimate.

2. On average there was an 8% overestimation of polygon features by area in the Landsat based disturbance mapping product when compared to SPOT 4/5 imagery. Interpreter bias associated with mapping polygon features was approximately +/–8% of this estimate.

3. Interpreter bias in mapping linear features was generally more pronounced in landscapes with a high density of linear features such as those in the western boreal. There was variation in both the detection and labelling of linear features amongst the individual interpreters. Seismic, road and pipeline class types were prone to error unless associated ancillary data were available for confirmation.

4. Interpreter bias in mapping polygon features was evident although less so than with linear features. Polygon features were reliably detected with less than a 1% error of omission; however, labelling of polygons such as cutblock, mine, settlement and

oil/gas class types were confused in areas with multiple disturbances. When ancillary data were available class type labelling was more reliable for polygon features, particularly for oil and gas.

5. Overall patterns of individual interpreter bias were consistent across all evaluated herds in the eastern and western boreal and for linear and polygon features. In other words, individual interpreters were making consistent decisions on a day-to-day basis regarding the mapping process, with each having their own particular bias. Interpreter variation should be considered when using the disturbance map product.

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