Time Series Analysis of Anthropogenic Disturbance in the Broadback River Watershed, Quebec

Executive Summary

This bulletin presents the results of time series analyses of anthropogenic industrial disturbance in the Broadback River watershed in northern Quebec, as well as an area to the south and east. The key findings are:

- Within the Broadback River watershed, linear disturbances increased from 468.8 km in 1980 to 4,298 km in 2015. Roads comprise the majority (92%) of these features; there were 339 km in 1980 and these had increased to 3,954 km by 2015. Transmission or power line corridors accounted almost 8% (329 km) of all linear disturbances.
- Polygonal, or area-based, disturbances increased from 2.8 km^2 in 1980 to 1,149.6 km^2 in 2015. Logging cutblocks account for 98.5% of the polygonal disturbances; there were 0.25 km^2 of logging cutblocks in 1980 but these had increased to 1,132.5 km^2 by 2015.
- The buffered anthropogenic disturbance footprint in the Broadback River watershed grew from just over 2% (455.46 km^2) in 1980 to 20% (4,294 km^2) by 2015. However, 27% of the watershed within the commercial forest zone has anthropogenic disturbance.
- The area south and east of the Broadback River watershed is much more disturbed, having a linear disturbance density of 0.5 km/km^2 by 2015 compared to 0.2 km/km^2 in the Broadback. The buffered anthropogenic disturbance footprint affects 50% of the southern study area, much higher than that of the Broadback River watershed.
- Cree traplines have been significantly impacted by the cumulative anthropogenic disturbance footprint. As of 1980, 20 traplines intersecting the Broadback River watershed had no disturbance and the remaining traplines were all under 25% disturbed. By 2015, only 4 traplines in the watershed had no anthropogenic disturbance, while 18 had over 25% disturbance.
- The traplines in the southern study area have even higher levels of disturbance. In 1980, 16 traplines had no disturbance while 8 had more than 10% disturbance. By 2015, only 1 trapline remained undisturbed while 22 traplines had over 50% disturbance. The average percent of buffered anthropogenic disturbance increased from 6.2% to 44%.
- The results of GFWC's time-series mapping of human disturbances in the Broadback River watershed and area south and east of it, reveal a steady increase in both linear and area-based disturbances, as well as cumulative buffered disturbances. Logging and associated road development are the most significant contributors the cumulative growth of the human impacts. However, there are still opportunities to ensure that further development is minimized in the watershed.

Introduction

The Broadback River watershed is located in Northwestern Quebec, at the southern end of James Bay (Map 1).[1] The Cree have lived in this watershed and the surrounding region, known as Eeyou Istchee to the Cree, for centuries and they use the area extensively for hunting, fishing, and trapping. The watershed contains all or portions of fifty Cree traplines (GCC 2011), defined as "an area where harvesting activities are by tradition carried on under the supervision of a Cree tallyman"[2](JBNQA 1975, section 24).

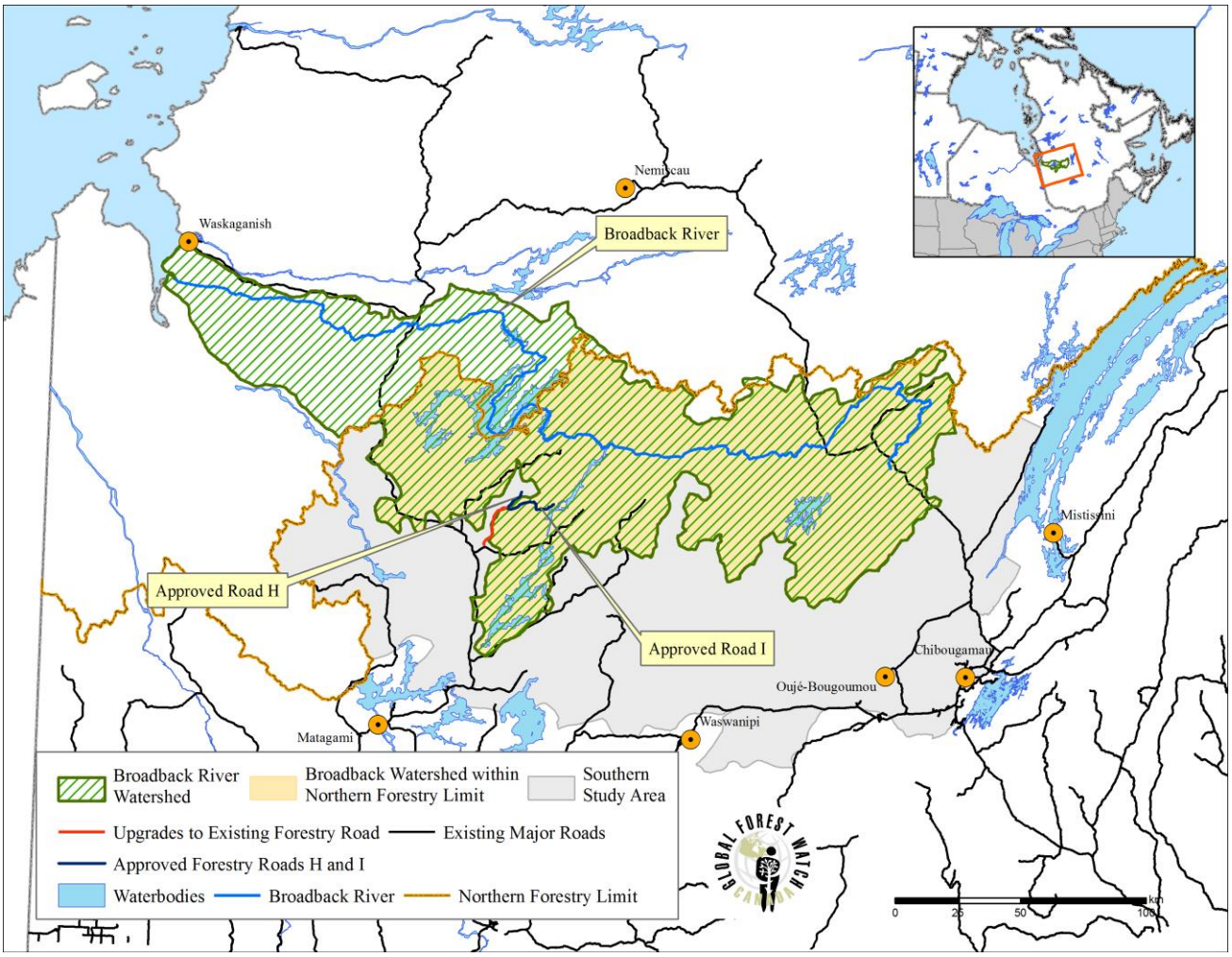
The watershed, and Eeyou Istchee as a whole, also have a history of industrial development, including hydropower developments (Map 2). However, the Cree and Quebec government agreed to the removal of the Broadback River from consideration for hydropower development in the Paix des Braves Agreement (2002). The northern limit of commercial forestry dissects the Broadback River watershed, with 70% (14,818 km^2) south of that limit (MFFP 2016b). Forest management units cover 54% (11,355 km^2), once protected areas are omitted (MFFP 2016a). There are no forest mills in the watershed. Mineral claims cover 5% (1,075 km^2) of the Broadback River watershed (MRNF 2016). There are no active mines within the watershed, though there are some to the south that produce zinc, copper, gold, and silver (Natural Resources Canada 2016).

Although the Broadback watershed already has some protected areas, the Cree have since proposed a watershed conservation plan for the Broadback River that protects some of the last remaining intact forests within the commercial boreal forest (GCC/CRA 2013).[3] The Cree Nation Government and the Quebec Government announced an expansion of several protected areas in the watershed in July 2015 (GCC 2015). As of early 2015, 2,968 km^2 (14%) of the Broadback River watershed was in protected areas (IUCN and UNEP-WCMC 2016), with the July 2015 announcement adding a further 3,056 km^2 (14.5%). However, the 2015 expansion still falls short of the Crees' vision for protecting the watershed; a further 6,388 km^2 of protected lands in the Broadback River Valley is required to fulfill their vision (see Map 3).[4]

[1] The vast majority (17,987 km^2 or 85%) is in the boreal shield ecozone while 3,162.9 km^2 (15%) falls within the Hudson Plains (Natural Resources Canada 2010).
[2] A tallyman is "a Cree person recognized by a Cree community as responsible for the supervision of harvesting activity on a Cree trapline" (JBNQA 1975, section 24).
[3] The Cree conservation plan included proposals for both parks and protected areas designations of 9,355 km^2 and a watershed management plan for a special management buffer zones of 10,866 km^2 (GCC/CRA 2013).
[4] There were proposals for two proposed forestry roads that would have breached the southern boundary of the Crees' Broadback protected areas proposal. However, based on an environmental assessment of the two roads, the Environmental and Social Review Committee (COMEX) recommended that these forestry roads be limited in scale in order to maintain the integrity of the Broadback watershed.

Global Forest Watch Canada (GFWC) decided to examine the status of anthropogenic disturbances in the Broadback River watershed (21,149.92 km^2)[5], We used Landsat satellite imagery to map over time, from 1980 to 2015, mapping both linear and polygonal (or area-based) disturbances. In order to understand how the watershed compares to the other portions of the commercial forestry zone, as well as the impact on traditional Cree harvesting areas, GFWC also mapped an area (19,674.21 km^2) to the south and east of the Broadback River watershed that extends as far south as Cree traplines, and as far east as Mistissini Lake (see Map 1). We also mapped the full extent of those traplines on the northern edge of the watershed, so we could undertake analyses on these. This bulletin contains the results of our mapping for both the watershed, as well as the area south and east of the watershed.

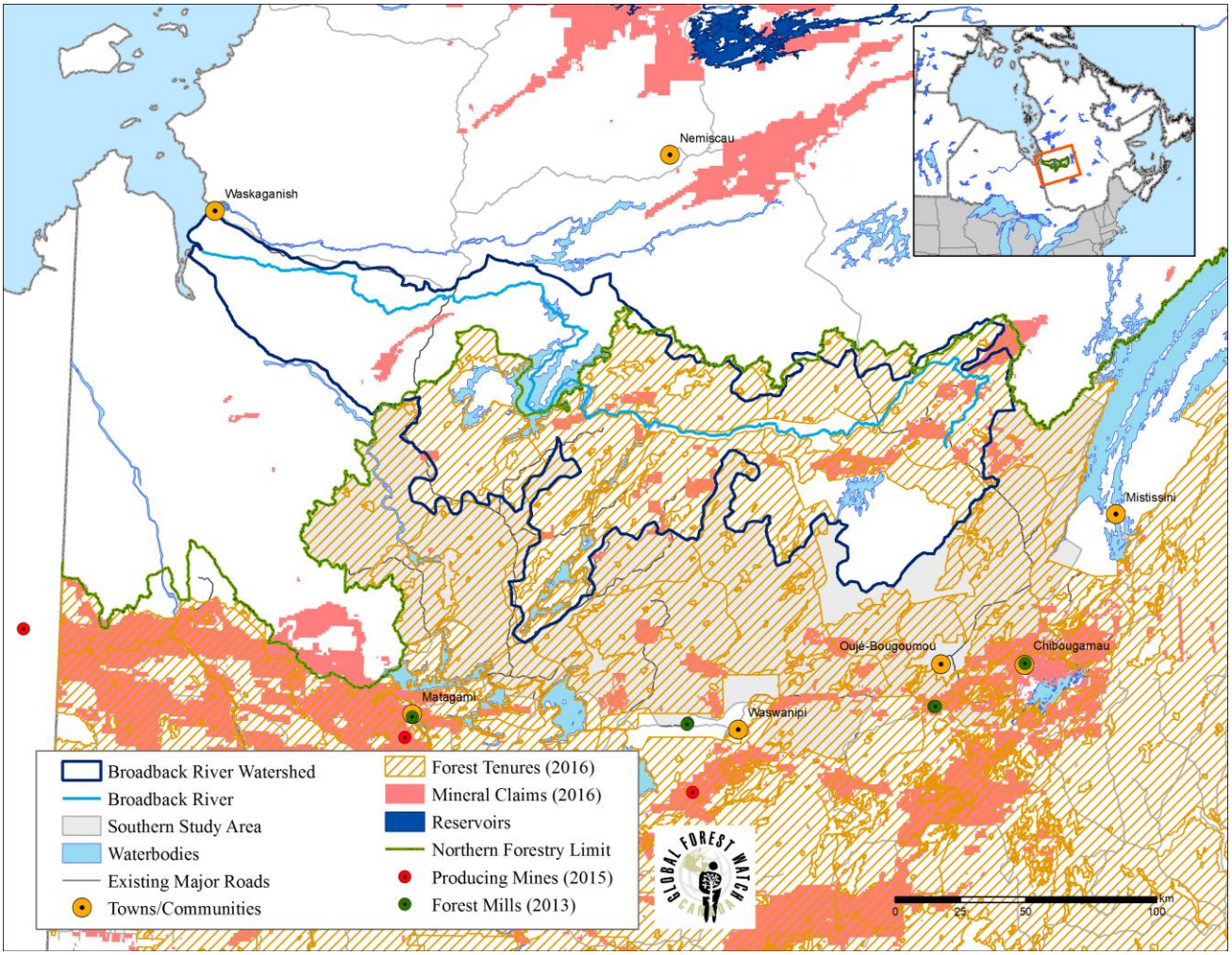
Map 1. Broadback River watershed and southern trapline area



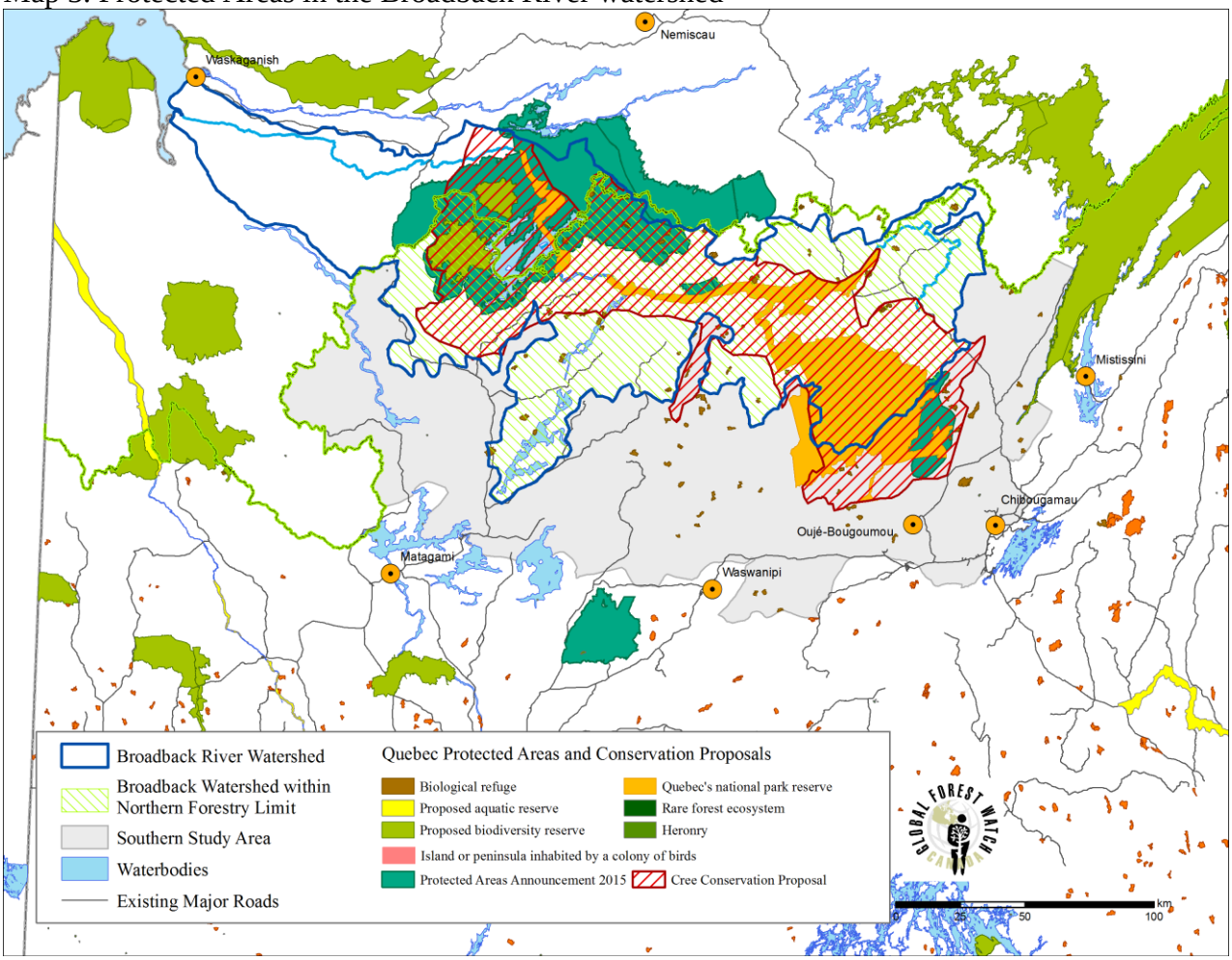
[5] GFWC extracted the Broadback watershed from the National Frameworks dataset for Fundamental Drainage Areas (Natural Resources Canada 2003), which comprised both the Upper and Lower Broadback Sub-Sub-Drainage Areas.

Photo 1. Broadback River, by the James Bay highway (left) and by Route du Nord (right)

Map 2. Industrial Tenures in the Broadback River watershed



Map 3. Protected Areas in the Broadback River watershed



Methods for Time Series Mapping

To conduct the time series mapping, GFWC collected Landsat satellite imagery at 5-year time intervals from 1980 to 2015 for the watershed, and the area to the south and east (see list of images in Appendix 1). We extended beyond the watershed to include all intersecting traplines, so we could conduct analyses on the traplines. We used Environment Canada's 2010 anthropogenic disturbance footprint dataset (Pasher *et al.* 2013) as the starting point for our times series disturbance mapping. Our mapping approach was as follows:

- We overlaid the Environment Canada dataset with the Landsat images for each 5-year time period and reviewed the scenes at a scale of 1:50,000.
- We clipped Environment Canada lines and polygons to match the extent of disturbance within each 5-year time period.

- We digitized linear features within cutblocks, which were not mapped by Environment Canada, to create a more complete linear disturbance dataset.
- During our examination of the Landsat imagery and Environment Canada dataset, we noted that some disturbances were misidentified. We removed these areas from the final dataset.
- GFWC mapped where features regenerated and were no longer visible on the Landsat images. We added a field to the datasets to indicate which year the feature became unrecognizable.
- We also mapped new disturbances that occurred between 2010 and 2015 based on the 2015 satellite images. This mapping was undertaken consistently with the methods used to create the Environment Canada layer and classified to the same anthropogenic disturbance categories.
- The entire dataset was then reviewed by a second interpreter at a 1:100,000 scale to identify and correct interpretation errors.
- We ran analyses to determine amounts and percentages of disturbances over time and by type.

GFWC then buffered both polygonal and linear disturbances for each time period by 500 meters to create an ecological buffer on the disturbance layers. A 500 meter buffer was used as Environment Canada demonstrated that the application of a 500 m buffer to mapped anthropogenic features best represents the combined effects of increased predation and avoidance on caribou population trends at the national scale (Environment Canada 2011). We used these layers to analyze change over time and to examine the impacts on traplines.

GFWC conducted all analyses in this report using ESRI ArcGIS 10 and map projection MTM 9, commonly used by the Government of Quebec for this region. Results are presented below as well as for the two study areas in a series of maps in Appendix 2.

Results of Time Series Mapping in the Broadback River Watershed

GFWC's time series mapping provides concrete data on the evolution of industrial activity and infrastructure development in the Broadback River watershed for the study period that spans 35 years (1980-2015).

Linear disturbances

There has been a continual growth of linear features in the Broadback River watershed during the 1980-2015 period (Table 1a, Map 4, see full suite of maps in Appendix 2). In 1980, there were

467.6 km of linear features and these had increased to almost 4,289 km by 2015. The 1980 disturbances accounted for 10.9% of the total mid-2015 linear disturbance footprint in the watershed. The largest amount of linear disturbance (1,169.6 km or 27% of all linear disturbances) occurred between 1995 and 2000. The other two most significant periods were 2000-2005 (806.6 km, or 18.8% of total linear footprint) and 2005-2010 (683 km, or 15.9% of the linear footprint). Just over 95% of the disturbances in the watershed have occurred within the commercial forest zone portion (Table 1b).

Table 1a. Linear disturbances in the Broadback River watershed

Year	Road (km)	Powerline (km)	Airstrip (km)	Unknown (km)	Total (km)	Period as % of total disturbance	Roads as % of period disturbances
(pre)1980	339.07	128.60	1.14		468.80	10.93	72.33
1980-1985	146.94	79.36			226.30	5.28	64.93
1985-1990	244.99	90.87			335.85	7.83	72.94
1990-1995	232.00	16.50			248.50	5.79	93.36
1995-2000	1,167.43			2.12	1,169.55	27.27	99.82
2000-2005	806.56				806.56	18.80	100.00
2005-2010	669.47	13.54			683.01	15.92	98.02
2010-2015	347.28			3.23	350.52	8.17	99.08
Total	**3,953.73**	**328.86**	**1.14**	**5.35**	**4,289.08**		**92.18**
% of 2015 disturbance	**92.18**	**7.67**	**0.03**	**0.12**			

Table 1b. Linear disturbances in the commercial forest zone of the Broadback River watershed

Year	Road (km)	Powerline (km)	Airstrip (km)	Unknown (km)	Total (km)	Period as % of all disturbance	Roads as % of period disturbances
(pre)1980	212.37	125.57			337.94	8.28	62.84
1980-1985	136.57	79.36			215.93	5.29	63.25
1985-1990	231.76	90.87			322.63	7.90	71.84
1990-1995	230.64	14.84			245.48	6.01	93.95
1995-2000	1,139.18			2.12	1,141.30	27.95	99.81
2000-2005	802.91				802.91	19.66	100.00
2005-2010	666.67				666.67	16.33	100.00
2010-2015	347.28			3.23	350.52	8.58	99.08

Total	**3,767.38**	**310.64**	**0.00**	**5.35**	**4,083.37**		**92.26**
% of 2015 disturbance	**92.26**	**7.61**	**0.00**	**0.13**			

Roads are the most extensive linear disturbance type in the watershed (see Photos 2 and 3), increasing from 339 km (72% of all linear disturbances) in 1980 to 3,953.7 km (92% of all linear disturbances) in 2015. Roads accounted for 90 to 100% of all new linear features in all 5-year time periods since the 1990-1995 period, both for the complete watershed and for the portion in the commercial forest zone. In the commercial forest zone, roads accounted for over 92% of all linear disturbances as of 2015.

Transmission, or power, line corridors (Photo 3) were the second most common linear disturbance type (7.6% of all linear disturbances). There were 128.6 km in 1980 and these had increased to 328.86 km in 2015 (Table 1a). Just over 310 km of these corridors were in the commercial forest zone portion of the watershed (Table 1b). There are minimal airstrips and unknown features in the watershed; altogether these totaled 6.49 km by 2015.There was minimal recovery of linear features within the watershed, with 6.78 km of roads regenerating by 2000, and a further 1.97 km between 2010-2015, for a total of 8.75 km.

Map 4. Linear disturbances mapped through time

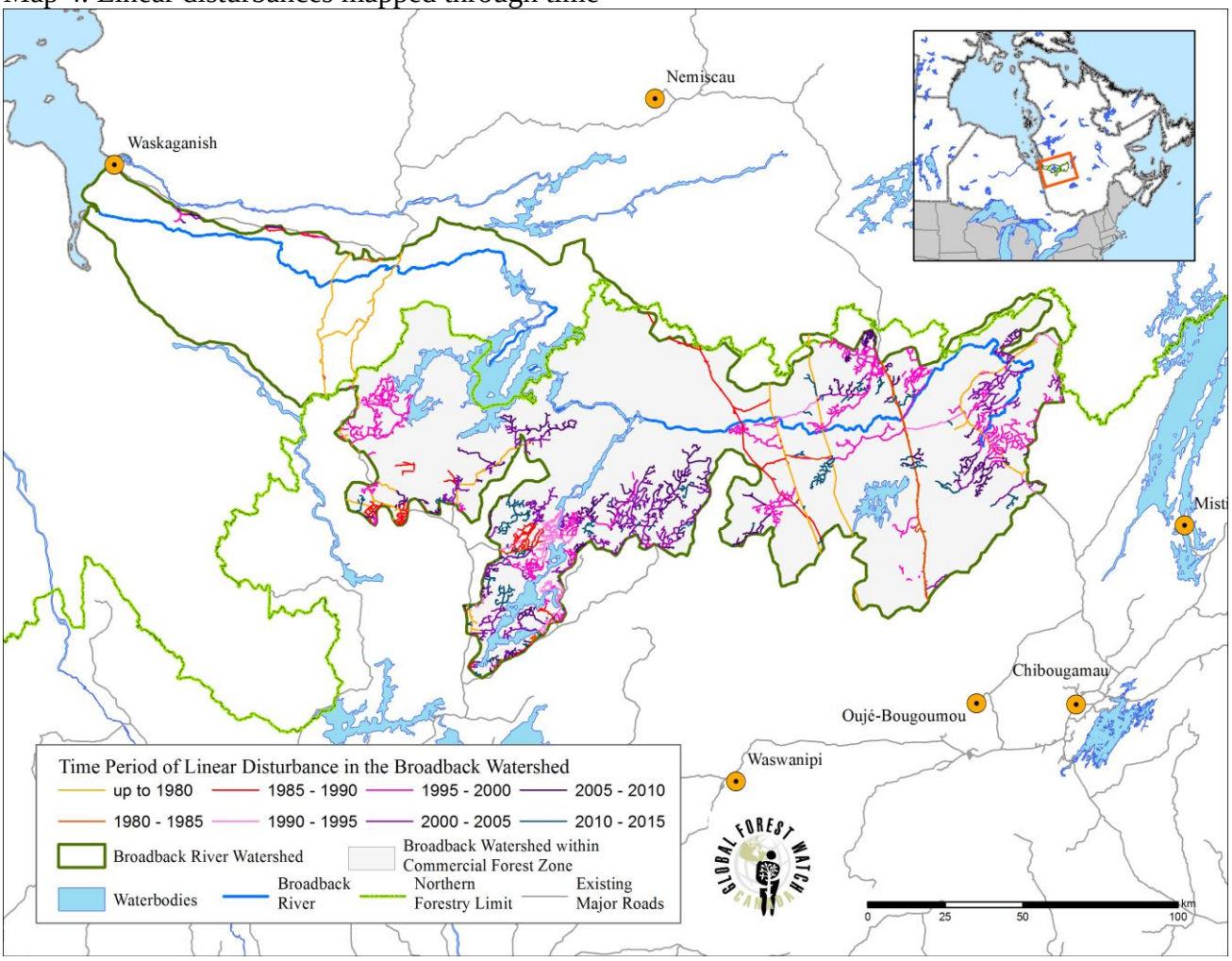


Photo 2. Recent logging road and cutblock (2010 -2015)

Photo 3. Route du Nord and transmission/power line corridors (1980 – 1985)

Polygonal disturbances

The Broadback River watershed contained 2.79 km^2 of polygonal disturbance in 1980, but these had increased to 1,150 km^2 by 2015 (Table 2a, Map 5, and full suite of maps in Appendix 2). Approximately 75% (862.7 km^2) of these area disturbances occurred between 1995 and 2010. The majority of these disturbances were logging cutblocks, as they accounted for 1,132 km^2, or 98.5%, of all the polygonal (area-based) disturbances by 2015 (see Photo 2). This amount represents a significant increase from the 0.25 km^2 of logging that existed in the watershed in 1980 (9% of the total disturbance as of 1980). Logging cutblocks account for 96.5% to 100% of all polygonal disturbances added in each five-year period, throughout the entire 35-year study period. GFWC mapped 0.07 km^2 of logging cutblocks that regenerated to such an extent they were no longer visible on the Landsat imagery as of 2010.

Mines[6] have a relatively small footprint in comparison, covering just over 8 km^2, or 0.72% of the polygonal disturbance footprint. Settlements and unknown features account for 8.9 km^2 of the disturbance footprint by 2015. Some unknown features are actually quarry sites, or mines (Photo 4). As a result of the small areas of other types of disturbances, the amounts and percentages of disturbance for the commercial forest zone portion of the watershed are not very different from the watershed as a whole, as evident in Table 2b.

Table 2a. Polygonal disturbances in the Broadback River watershed

Year	Cutblocks (km^2)	Mine (km^2)	Settlement (km^2)	Unknown (km^2)	Amount disturbance (km^2)	% of total disturbance	Cutblocks as % of period disturbances
(pre)1980	0.25	1.74	0.72	0.08	2.79	0.24	9.03
1980-1985	7.21			0.05	7.26	0.63	99.29
1985-1990	62.53				62.53	5.44	100.00
1990-1995	86.02	0.40	0.35	0.57	87.34	7.60	98.49
1995-2000	322.06	1.87	0.03	0.20	324.16	28.20	99.35
2000-2005	281.88	1.85			283.73	24.68	99.35
2005-2010	246.06	2.36		6.42	254.84	22.17	96.55
2010-2015	126.46			0.45	126.90	11.04	99.65
Total	**1,132.47**	**8.22**	**1.10**	**7.76**	**1,149.56**	**100.00**	**98.51**
% of 2015 disturbances	**98.51**	**0.72**	**0.10**	**0.68**			

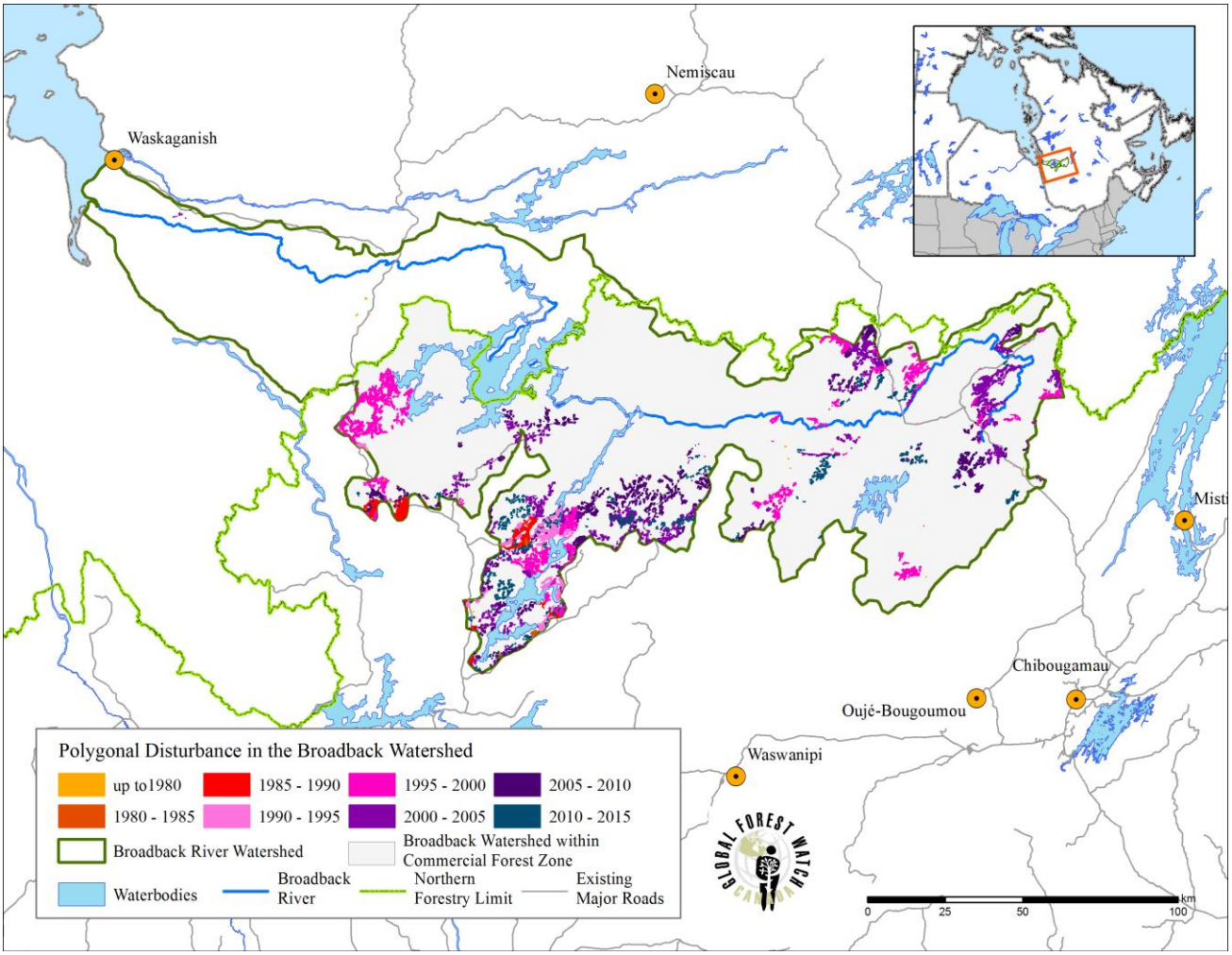
[6] Mines are defined in the Environment Canada dataset as areas of exposed land that are associated with mineral or aggregate extraction operations, including: quarries, slag heaps, tailing piles, tailings ponds and associated mining infrastructure. Waste water and holding ponds associated with industrial activities, and any other artificial water bodies that were not true reservoirs, were included in this category (Environment Canada 2011).

Table 2b. Polygonal disturbances in the commercial forest zone of the Broadback River watershed

Year	Cutblocks (km^2)	Mine (km^2)	Settlement (km^2)	Unknown (km^2)	Amount disturbance (km^2)	% of total disturbance	Cutblocks as % of period disturbances
(pre)1980	0.25	1.22	0.24	0.08	1.78	0.16	14.12
1980-1985	7.21			0.05	7.26	0.63	99.29
1985-1990	62.53				62.53	5.46	100.00
1990-1995	86.02	0.28		0.57	86.86	7.58	99.03
1995-2000	321.21	1.87	0.03	0.20	323.30	28.20	99.35
2000-2005	281.70	1.32			283.02	24.69	99.54
2005-2010	246.06	2.12		6.42	254.60	22.21	96.65
2010-2015	126.46			0.45	126.90	11.07	99.65
Total	**1,131.45**	**6.80**	**0.27**	**7.76**	**1,146.27**	**100.00**	**98.71**
% 2015 disturbance	**98.71**	**0.59**	**0.02**	**0.68**	**100.00**		

Photo 4. Quarry pit, categorized as unknown disturbance (1990 – 1995)

Map 5. Polygon disturbances by time period



Buffered anthropogenic disturbance footprint

The combined linear and polygonal disturbances buffered by 500 meters reveals a significant increase in disturbances in terms of total area in the Broadback River watershed (Table 3a). In 1980, there were 455.46 km^2 of buffered anthropogenic disturbance, representing 2.15% of the watershed. Areas mapped in subsequent time periods ranged from a low of 169.85 km^2 in 1980-1085 to a high of 1,348 km^2 between 1995-2000. The area of buffered disturbance that added to the cumulative footprint (that is, did not overlap with previous buffered disturbances) ranged from 162.56 km^2 in the 1980-1985 period, to 1,189.5 km^2 betweeen 1995-2000. By 2015, there was a combined buffered disturbance footprint of 4,293.9 km^2, representing approximately 20% of the entire watershed. Further analysis of the data reveals that most of the total anthropogenic disturbance footprint (4,101.4 km^2) is within the commercial forest zone of the watershed, which is actually over 27% impacted, as compared to the 20% of the total watershed (Table 3b). Map 6 illustrates the cumulative

buffered anthropogenic disturbance footprint as of mid-2015; a full series of maps is provided in Appendix 3.

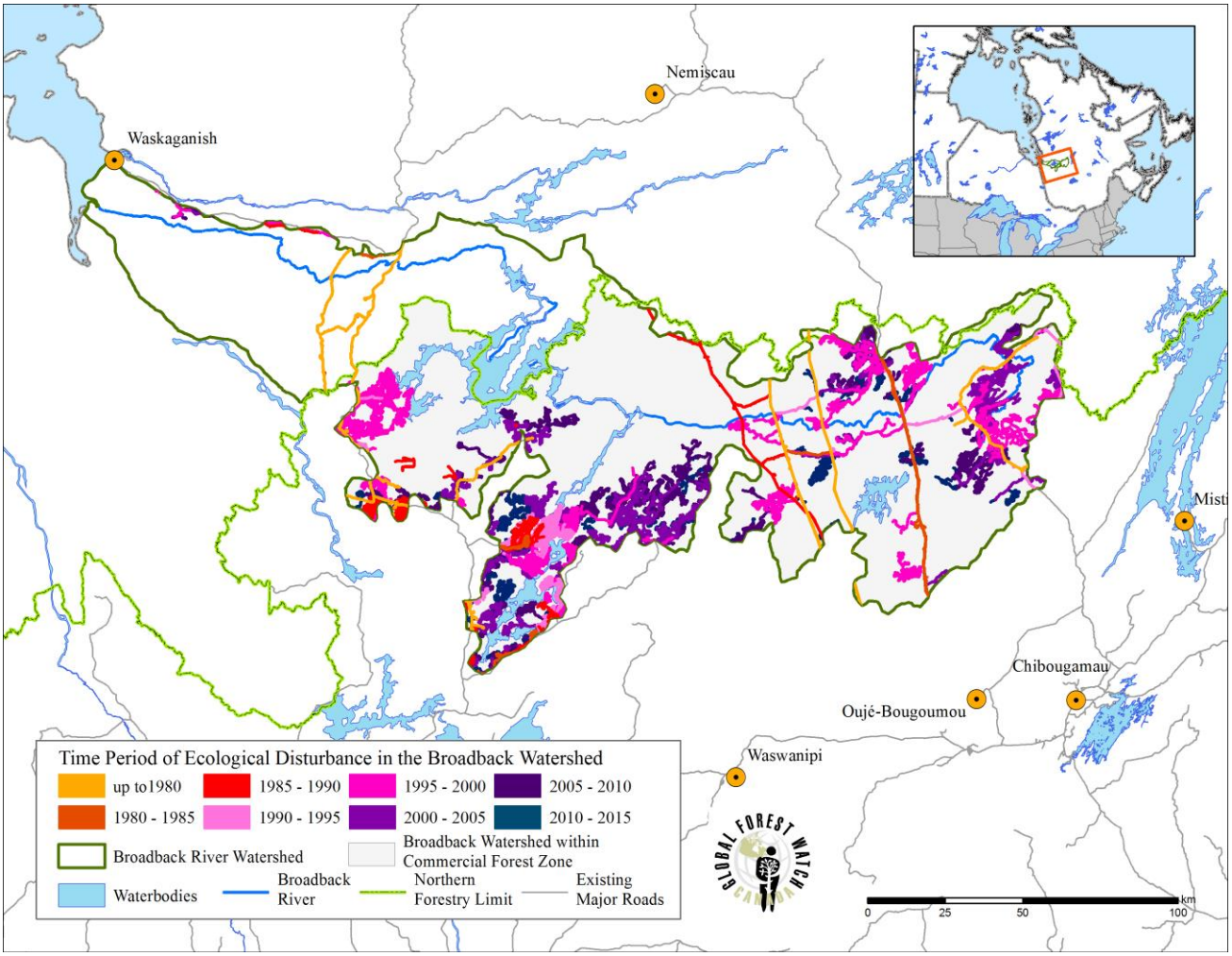
Table 3a. Buffered anthropogenic disturbance footprint in the Broadback River watershed

Year	Buffered anthropogenic disturbances (km^2)	Portion that does not overlap previous buffered disturbances (km^2)	Cumulative buffered disturbance (km^2)	Cumulative watershed disturbed (%)
(pre)1980	455.46	455.46	455.46	2.15
1980-1985	169.85	162.56	618.02	2.92
1985-1990	351.40	303.85	921.87	4.36
1990-1995	326.53	249.63	1171.5	5.54
1995-2000	1,348.04	1,189.46	2,360.96	11.16
2000-2005	1,204.73	871.12	3,232.08	15.28
2005-2010	1,117.77	715.00	3,947.08	18.66
2010-2015	661.54	346.78	4,293.86	20.30
Total	**Not applicable**	**Not applicable**	**4,293.86**	**Not applicable**

Table 3b. Buffered anthropogenic disturbance footprint in the commercial forest zone of the Broadback River watershed

Year	Buffered anthropogenic disturbances (km^2)	Portion that does not overlap previous buffered disturbances (km^2)	Cumulative buffered disturbance (km^2)	Cumulative watershed (forest zone) disturbed (%)
(pre)1980	324.51	324.51	324.51	2.19
1980-1985	156.35	153.34	477.34	3.22
1985-1990	337.39	289.84	767.69	5.18
1990-1995	320.60	246.32	1,014.01	6.84
1995-2000	1,317.48	1,165.59	2,179.60	14.71
2000-2005	1,194.85	865.58	3,045.18	20.55
2005-2010	1,098.85	709.47	3,754.65	25.34
2010-2015	661.54	346.78	4,201.43	27.68
Total	**Not applicable**	**Not applicable**	**4,101.43**	**Not applicable**

Map 6. Buffered anthropogenic disturbance footprint in the Broadback River watershed



Results of Time Series Mapping South of the Broadback River Watershed

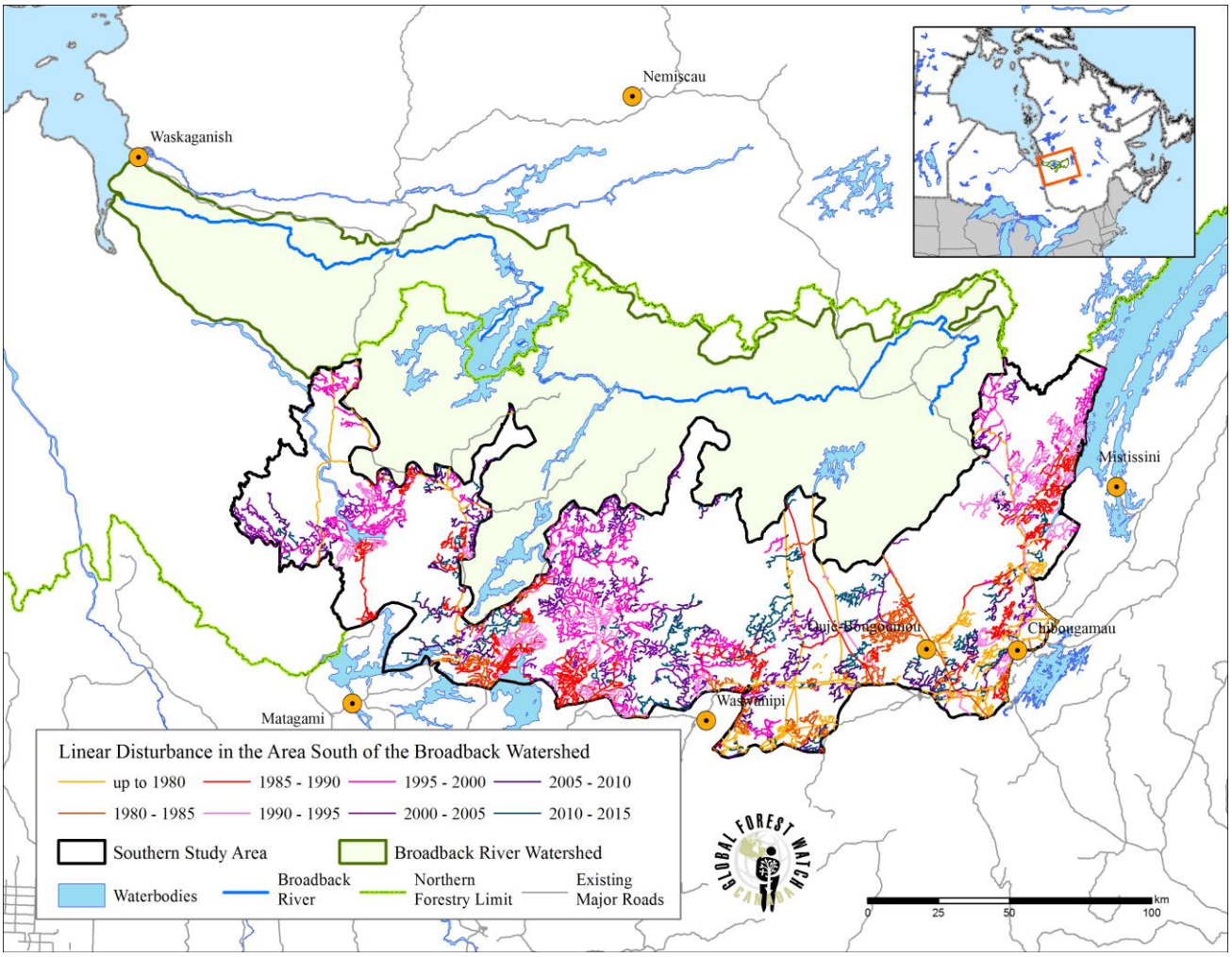
GFWC's time series mapping provides concrete data on the evolution of industrial activity and infrastructure development in the area south of Broadback River watershed for the 35 year (1980-2015) study period (see maps in Appendices 2 and 3).

Linear disturbances

There has been a continual growth of linear features in the area south of the Broadback during the 1980-2015 period (Table 4, Map 7). In 1980, there were 1,407,1 km of linear features and these had increased to 10,289 km by 2015. The (pre)1980 disturbances accounted for 13.7% of the total mid-2015 linear disturbance footprint in the area. There was a steady increase of 11-16% per 5-year period between 1985 and 2005. The linear density increased from 0.07 km/km^2 in 1980 to 0.52

km/km^2 in 2015, which is much higher than the Broadback watershed density of 0.02 km/km^2 in 1980 to 0.2 km/km^2 in 2015.

Map 7. Linear disturbances by time period in the area south of the Broadback River watershed



Similar to the Broadback River watershed, roads account for the majority of all linear disturbances, 94% in this case (compared to 92.3% in the watershed). Each 5-year period had well over 1,000 km of roads (200 km/year) constructed, except the 1985-1990 and 2010-2015 periods, which had 889 and 917 km, respectively. Roads are sometimes built into older logging areas (Photo 5).

Transmission, or powerline, corridors account for almost 5.5% (561.1 km) of the linear features, and these were all developed between (pre)1980 and 1995. There are also some railway lines (42 km) and airstrips (1.8 km) in this area, compared to none of either feature in the Broadback River watershed. These were all in place by the start of the middle of 1980 (see railway line in Photo 6).

Table 4. Linear disturbances in the area south of the Broadback River watershed

Year	Road (km)	Power-line (km)	Airstrip (km)	Railway (km)	Un-known (km)	Total (km)	Period as % of total disturbance	Roads as % of period disturbances
(pre)1980	1,097.74	258.46	1.81	42.07	7.63	1,407.71	13.68	77.98
1980-1985	889.40	71.64				961.04	9.34	92.55
1985-1990	1,545.95	77.01				1,622.96	15.77	95.25
1990-1995	1,113.60	153.98				1,267.57	12.32	87.85
1995-2000	1,824.11					1,824.11	17.73	100.00
2000-2005	1,282.91					1,282.91	12.47	100.00
2005-2010	1,005.55					1,005.55	9.77	100.00
2010-2015	917.27					917.27	8.91	100.00
Total	**9,676.53**	**561.83**	**1.81**	**42.07**	**7.63**	**10,289.13**	**100.00**	**94.81**
% of 2015 disturbance	**94.05**	**5.45**	**0.02**	**0.41**	**0.07**	**100.00**		

Photo 5. Example of older clearcut (1980 – 1985) with recent road (2005 – 2010)

Photo 6: Railway in the southern study area

Polygonal disturbances

Compared to the Broadback River watershed, the area south of the Broadback, contained 370.9 km^2 of polygonal disturbances in 1980. This amount represented 9.5% of the total area-type disturbances of 3,923.8 km^2 by 2015, a much higher initial amount than the Broadback's starting point of 0.24% (Table 5, Map 8). The area had a steady addition of polygonal features per 5-year period from 1980 through to 2015, peaking in the 1985-2005 period. The total area of disturbance added per 5-year period decreased during the last 10 years (2005-2015).

The majority of these disturbances were logging cutblocks, as they accounted for 3,847 km^2, or 98%, of all the polygonal (area-based) disturbances by 2015 (Photos 7 and 8). This amount represents a significant increase from the 325 km^2 of logging that existed in the watershed in 1980 (98% of the total area disturbances as of 1980). GFWC mapped 29 km^2 of logging cutblocks that regenerated to such an extent they were no longer visible on the Landsat imagery of 2015.

Mines had a relatively small footprint in comparison, covering just over 15 km^2, or 0.4% of the polygonal disturbance footprint. Settlements, such as the Cree community of Oujé-Bougoumou (Photo 9) and unknown features account for 27 km^2 of the disturbance footprint by 2015.

Map 8. Polygonal disturbance by time period in the area south of the Broadback watershed

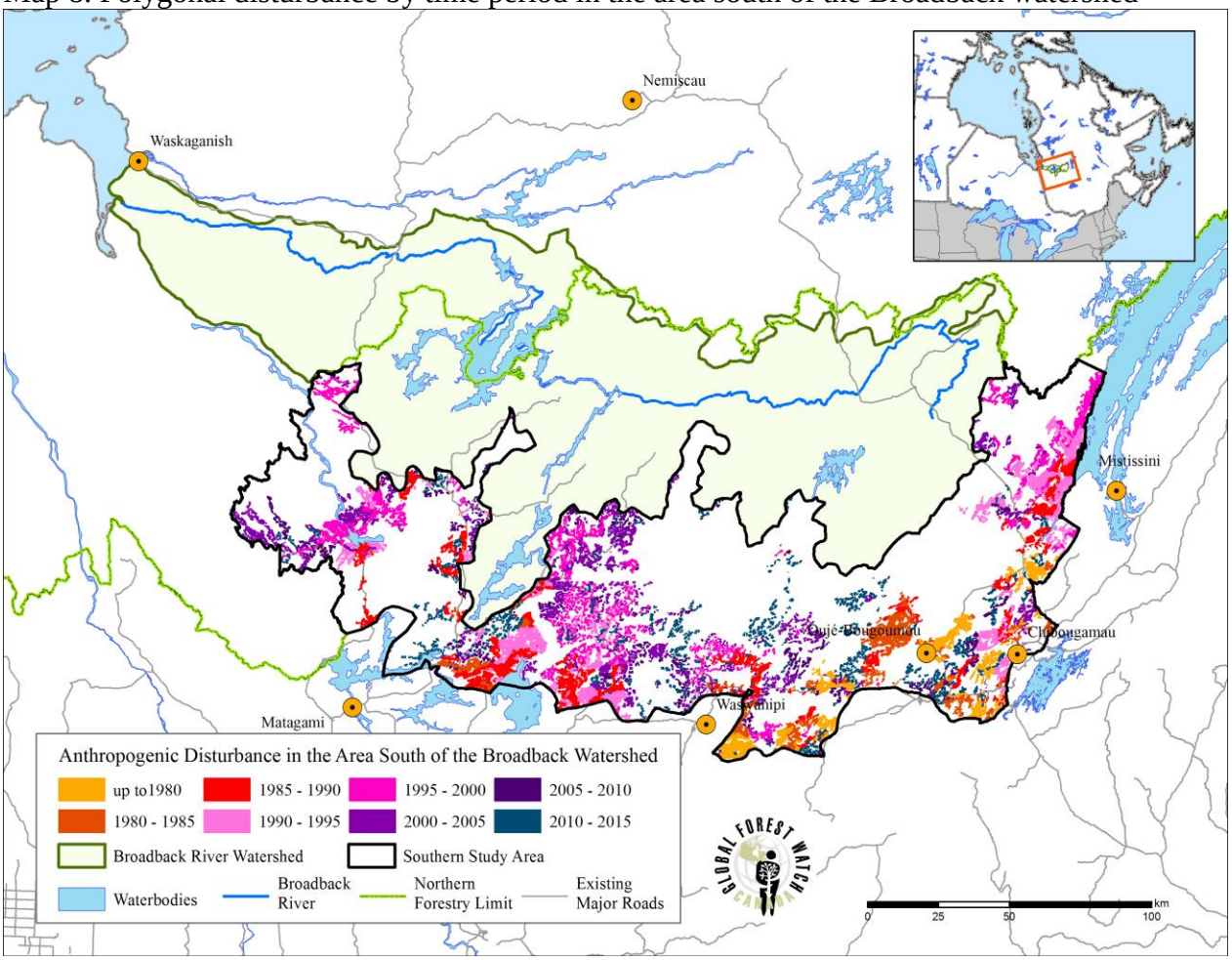


Photo 7. Example of logging cutblock (2005 – 2010)

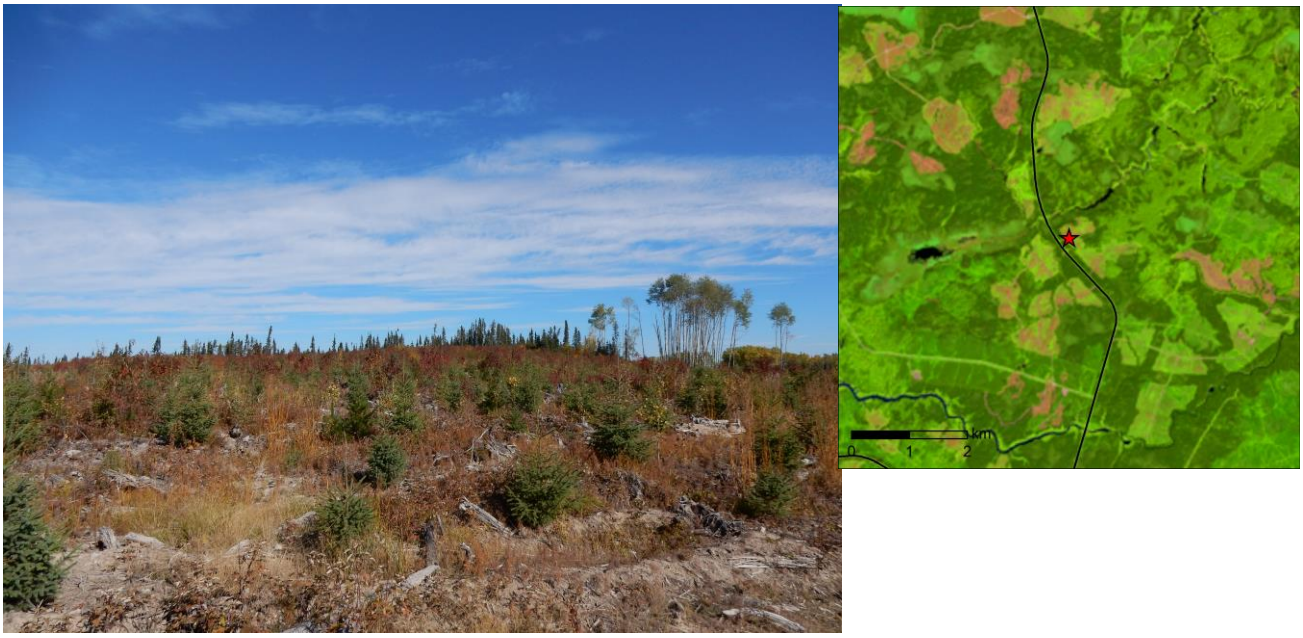


Table 5. Polygonal disturbances south of the Broadback watershed

Year	Agriculture (km^2)	Cutblocks (km^2)	Mine (km^2)	Settlement (km^2)	Unknown (km^2)	Amount Disturbance (km^2)	% of total disturbance	Cutblocks as % of period disturbances
(pre)1980	31.53	324.91	3.02	9.34	2.09	370.89	9.45	87.60
1980-1985	1.48	357.59	3.73	1.70	0.05	364.55	9.29	98.09
1985-1990		672.79	0.62	1.07	2.38	676.87	17.25	99.40
1990-1995	0.24	634.08	0.95	0.69	0.12	636.08	16.21	99.69
1995-2000	0.08	654.09	1.55	0.66		656.39	16.73	99.65
2000-2005	0.55	574.02	2.45	1.28	0.51	578.81	14.75	99.17
2005-2010	0.37	258.24	2.61	1.12	1.41	263.76	6.72	97.91
2010-2015		371.53	0.26	0.04	4.58	376.42	9.59	98.70
Total	**34.25**	**3,847.26**	**15.20**	**15.91**	**11.14**	**3,923.76**	**100.00**	**98.05**
% of 2015 disturbances	**0.87**	**98.05**	**0.39**	**0.41**	**0.28**			

Photo 8. Another example of a logging cutblock and logging road (2010 – 2015)

Buffered anthropogenic disturbance footprint

The combined linear and polygonal disturbances buffered by 500 meters reveals a significant increase in disturbances in the area south of the Broadback River watershed (Table 6). In 1980, there were 1,513.2 km^2 of buffered anthropogenic disturbance, representing 7.7% of the watershed. Buffered areas by time period ranged from 1,169.7 km^2 in 1980-1985, to a high of 2,444 km^2 between 1995-2000. Amounts that were new in subsequent years, that is, that did not overlap previous areas of buffered disturbance, ranged from 807.8 km^2 between 2010-2015, to 1,881.2 km^2 between 1995 and 2000. By 2015, there was a combined buffered disturbance footprint of 9,881.5 km^2, representing slightly more than 50% of the entire southern study area, which is significantly higher than the 20% in the Broadback River watershed or 27% in the commercial forest zone of the Broadback River watershed. Map 9 illustrates the total buffered anthropogenic disturbance footprint as of mid-2015; a series of maps are provided in Appendix 3.

Map 9. Buffered anthropogenic disturbance footprint for area south of Broadback watershed

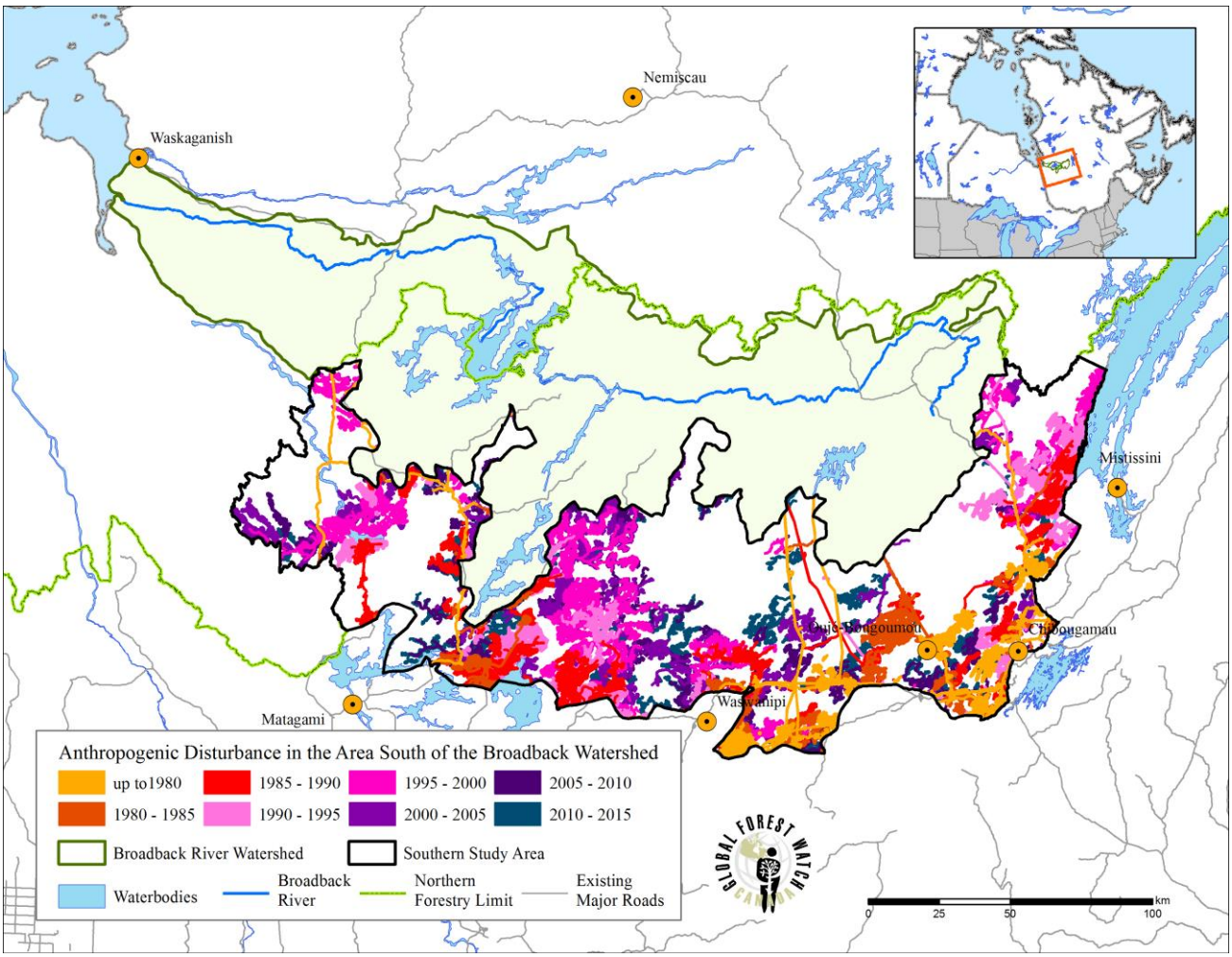


Table 6. Buffered anthropogenic disturbance footprint for area south of Broadback

Year	Buffered anthropogenic disturbances (km^2)	Portion that does not overlap previous buffered disturbances (km^2)	Cumulative buffered disturbance (km^2)	Cumulative watershed disturbed (%)
(pre)1980	1,513.18	1,513.18	1,513.18	7.69
1980-1985	1,169.73	867.04	2,380.22	12.10
1985-1990	1,920.71	1,508.78	3,889.00	19.77
1990-1995	1,787.91	1,142.22	5,031.22	25.57
1995-2000	2,443.96	1,881.18	6,912.40	35.13
2000-2005	2,248.51	1,307.67	8,220.07	41.78
2005-2010	1,528.86	853.66	9,073.73	46.12
2010-2015	1,778.55	807.81	9.881.54	50.23
Total	**Not applicable**	**Not applicable**	**9,881.54**	**Not applicable**

Photo 9. Community of Oujé-Bougoumou

Cree Traplines and Disturbance

As noted earlier, 50 traplines intersect the Broadback watershed. Forty-eight traplines intersect the southern study area, and 31 intersect both the watershed and the southern study area. These traplines have varying levels of buffered anthropogenic disturbance (Map 10, Table 7). In 1980, 20 traplines intersecting the Broadback River watershed had no disturbance and the remaining traplines were all under 25% disturbed. The average percent of trapline disturbance was 2.3%. By 2015, only 4 traplines in the watershed had no anthropogenic disturbance, while 18 had over 25% disturbance.

The southern study area shows a greater increase in the level of disturbance within the traplines. In 1980, 16 traplines had no disturbance and 8 had more than 10% disturbance. By 2015, one trapline remained undisturbed while 22 traplines had over 50% disturbance. The average percent of buffered anthropogenic disturbance increased from 6.2% to 44%.

Map 10. Percent buffered anthropogenic disturbance within Cree traplines

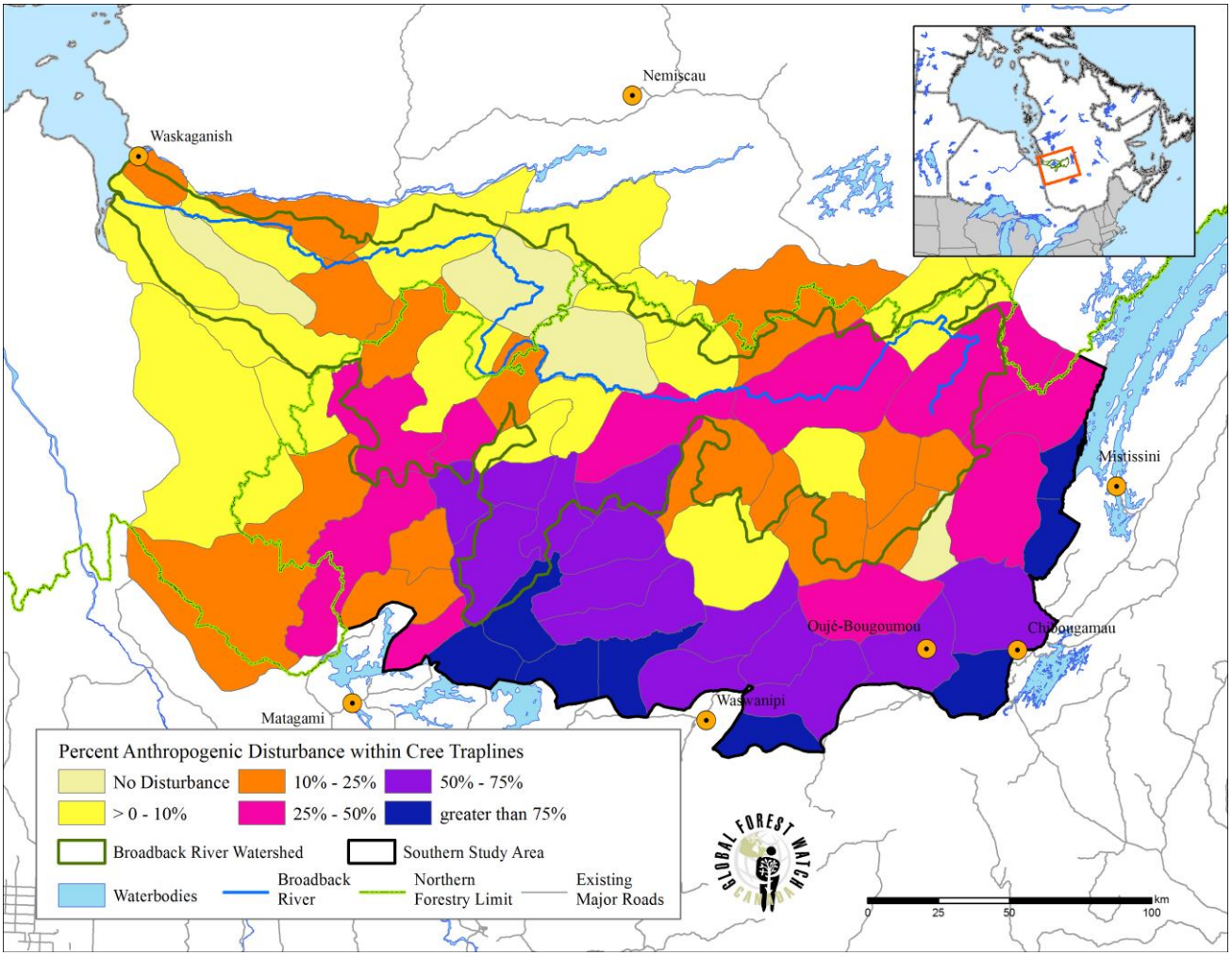


Table 7. Buffered anthrogenic disturbance in Cree traplines

Anthropogenic Disturbance within Trapline (%)	Traplines in Broadback Watershed (number)		Traplines in Southern Area (number)	
	Pre-1980	2015	Pre-1980	2015
0% (none)	20	4	16	1
>0-<10%	28	15	24	6
10-<25%	2	13	4	10
25-<50%		10	3	9
50-<75%		6	1	14
Greater than 75%		2		8
Average % Anthropogenic Disturbance	**2.26**	**24.56**	**6.17**	**43.97**

Conclusion

The Broadback River watershed in Quebec is considered an important cultural and ecological area. There are still significant areas of intact forest landscapes within the watershed, but humans have also made significant industrial development inroads into the Broadback River watershed, and even more so to the south and east of the watershed. The key findings from GFWC's time-series mapping for the Broadback River watershed are:

- Within the Broadback River watershed, linear disturbances increased from approximately 469 km in 1980 to 4,298 km in 2015. Roads comprise the majority (92%) of these features; there were 339 km in 1980 and these had increased to 3,953.7 km by 2015. Transmission or power line corridors accounted for 7.7% (328.9 km) of all linear disturbances by 2015.
- Polygonal, or area-based, disturbances within the Broadback watershed increased from 2.8 km^2 in 1980 to 1,149.6 km^2 in 2015. Logging cutblocks account for 98.5% of the polygonal disturbances; there were 0.25 km^2 of logging cutblocks in 1980 but these had increased to 1,132.5 km^2 by 2015.
- The buffered (total) anthropogenic disturbance footprint in the Broadback River watershed grew from 2.2% (455.46 km^2) of the watershed in 1980 to 20% (4,294 km^2) by 2015. However, 27% of the watershed within the commercial forest zone has cumulative anthropogenic disturbance.
- The area south and east of the Broadback River watershed is much more disturbed, having a linear disturbance density of 0.5 km/km^2 by 2015 compared to 0.2 km/km^2 in the Broadback. The buffered anthropogenic disturbance footprint accounts for 50% of the southern study area, much higher than that the 20% in the Broadback River watershed.
- Cree traplines have been significantly impacted by the cumulative anthropogenic disturbance. As of 1980, 20 traplines intersecting the Broadback River watershed had no disturbance and the remaining traplines were all under 25% disturbed. By 2015, only 4 traplines in the watershed had no anthropogenic disturbance, while 18 had over 25% disturbance.
- The traplines in the southern study area have even higher levels of disturbance. In 1980, 16 traplines had no disturbance and 8 had more than 10% disturbance. By 2015, only 1 trapline remained undisturbed while 22 traplines had over 50% disturbance. The average percent of buffered anthropogenic disturbance increased from 6.2% to 44%.

The results of GFWC's time-series mapping of human disturbances in the Broadback River watershed and area south and east of it, reveal a steady increase in both linear and area-based disturbances. Logging and associated road development are the most significant contributors the cumulative growth of the human impacts. However, while development incursions have already had impacts on the Broadback River watershed, there are still opportunities to ensure that further development is minimized.

References and Datasets

Canadian Forest Service. 2007. EOSD Land Cover Classification. Victoria BC: Canadian Forest Service, Pacific Forestry Centre. Dataset available at: https://ca.nfis.org/index_eng.html

Cheng, R. and P. Lee. 2014. *Canada's Industrial Concessions: A Spatial Analysis*. Global Forest Watch Canada. Dataset available at: http://globalforestwatch.ca/node/200.

Environment Canada. 2012b. Anthropogenic disturbance footprint within boreal caribou ranges across Canada - As interpreted from 2008-2010 Landsat satellite imagery (Updated using 2012 range boundaries). Wildlife and Landscape Science and Technology, Environment Canada. Available at: http://open.canada.ca/data/en/dataset/890a5d8d-3dbb-4608-b6ce-3b6d4c3b7dce.

Environment Canada. 2011. *Scientific Assessment to Support the Identification of Critical Habitat for Woodland Caribou (Rangifer tarandus caribou), Boreal Population, in Canada*. Ottawa, ON. 115pp. plus Appendices.

GCC (Grand Council of the Crees). 2015. "Cree Nation Government and Government of Quebec Sign the Agreement to Resolve the Baril-Moses Forestry Dispute". Press release July 13, 2015. Available at: http://www.gcc.ca/newsarticle.php?id=414. Accessed June 15, 2016.

GCC. 2011. Grand Council of the Crees (Eeyou Istchee) territory and sub-territories (Traplines) dataset.

GCC/CRA (Grand Council of the Crees (Eeyou Istchee)/Cree Regional Authority). 2013. *Broadback Watershed Conservation Plan*. Available at: http://www.eeyouconservation.com/broadback-watershed-conservation-plan.html Accessed June 2016.

Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." *Science* 342 (15 November): 850–53. Data available at: http://earthenginepartners.appspot.com/science-2013-global-forest.

IUCN and UNEP-WCMC 2016. The World Database on Protected Areas (WDPA) [On-line], July 2016, Cambridge, UK: UNEP-WCMC. Available at: www.protectedplanet.net.

JBNQA (*The James Bay and Northern Quebec Agreement*). 1975. Available at: http://www.gcc.ca/pdf/LEG000000006.pdf. Accessed July 2016.

Pasher, J., E. Seed, and J. Duffe. 2013. Development of boreal ecosystem anthropogenic disturbance layers for Canada based on 2008 to 2010 Landsat imagery. *Can. J. Remote Sensing* 39 (1): 42-58. Data available at: http://open.canada.ca/data/en/dataset/afd0ce47-17c3-445c-b823-2f86409da2e0.

MDDELCC (Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques Québec). 2016. Certificat d'autorisation 3214-05-075. Available at: http://www.mddelcc.gouv.qc.ca/evaluations/projet-sud.htm. Accessed June 2016.

MFFP (Ministère des Forêts, de la Faune et des Parcs Québec). 2016a. Les unités d'aménagement (version avril 2016). Direction de la gestion de l'information forestière.

MFFP (Ministère des Forêts, de la Faune et des Parcs Québec). 2016b. La limite nordique des forêts attribuables. Direction de la gestion de l'information forestière.

MRNF (Ministère des Ressources naturelles et de la Faune Québec). 2016. Mining rights digital data. Ministère des Ressources naturelles et de la Faune, Direction générale de la gestion du milieu minier. Available at: https://mern.gouv.qc.ca/mines/titres/titres-gestim.jsp

Natural Resources Canada. 2016. Producing Mines Data. Minerals and Metals Sector and National Energy Board. Geological Survey of Canada Map 900A, 65th Edition. Available at: www.geogratis.ca

Natural Resources Canada. 2010. Terrestrial Ecozones - Atlas of Canada, 6th Edition. Government of Canada, Natural Resources Canada, Earth Sciences Sector, Atlas of Canada. Available at: www.geogratis.ca.

Natural Resources Canada. 2003. Atlas of Canada 1,000,000 National Frameworks Data, Hydrology - Major River Basin. Government of Canada; Natural Resources Canada; Earth Sciences Sector; Canada Centre for Mapping and Earth Observation. Available at: http://geogratis.gc.ca/api/en/nrcan-rncan/ess-sst/14f77ebc-5600-5e33-9565-1bd58086f98d.html#distribution

Review Process

A key principle of GFWC is that transparency and accountability are essential for developing improved forest management. In the interest of promoting open, public, and transparent information policies, all major GFWC projects include a review process and the publication of a summary of the major comments provided by the reviewers, including how these comments were addressed.

GFWC had prepared a report that reported on analyses using existing datasets for a larger study area around the Broadback River watershed. We sent out invitations to review an earlier draft report to academic experts as well as to representatives from government, industry, ENGOs, and First Nations groups. We also posted a review invitation to the general public on the front page of our website. The review materials were available for a one-month period. We received comments from a few NGOs and a forestry company.

These comments provided input on the study area, and requested some clarification of terminology, such as traplines, polygonal disturbances. We have tried to address all of these in this current report. Our major adjustment was to focus the revised report solely on results of the timeseries mapping and analyses.

We have also adjusted the study area, as we received comments related to what some felt was an arbitrary boundary that was not pertinent to the Broadback watershed. We have addressed this by focusing our analysis on two scales: the Broadback watershed proper as an ecological unit (while also presenting results on the commercial forestry portion of the watershed), as well as a study area to the south of the watershed that provides a comparative area for analysis that falls within the commercial forestry zone and the southern limit of Cree. We have used the northern edge of the watershed as the main northern limit, although we do provide some results that include the traplines portions that extend north of the watershed.

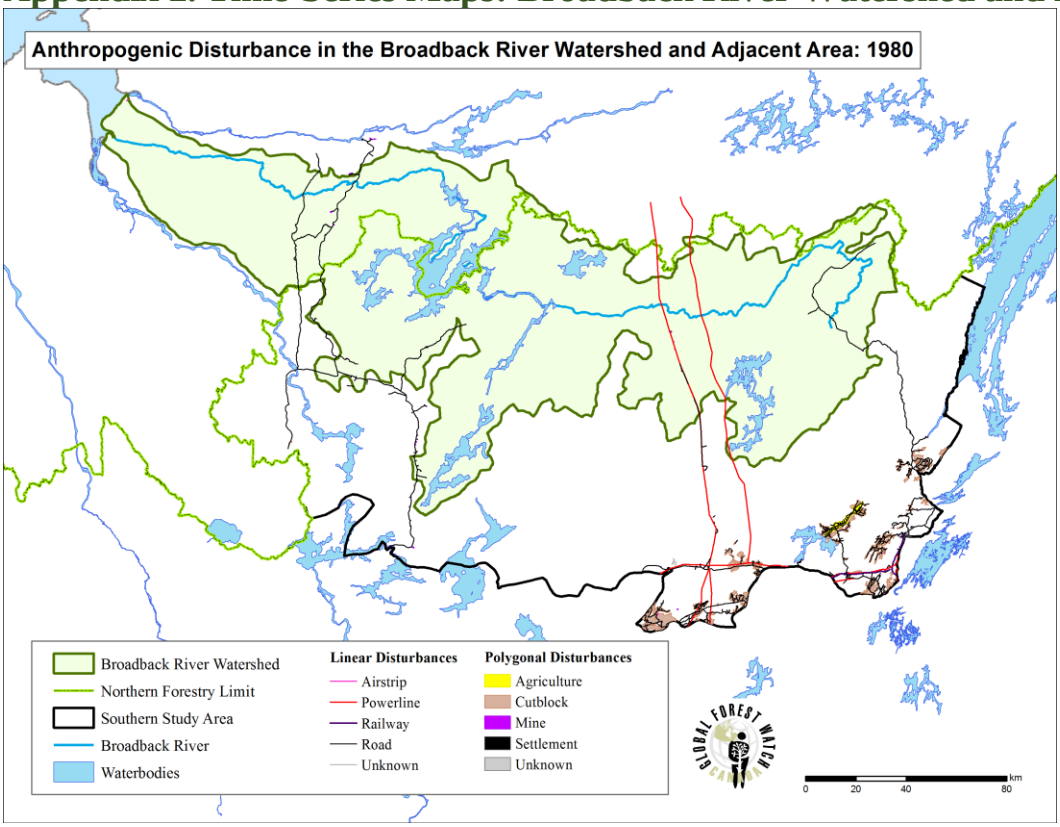
GFWC also received comments that we did not explain either the change in logging under the Paix-des-Braves agreement or the issue of salvage logging. GFWC feels that these issues are beyond the scope of our analysis. In addition, Environment Canada maps salvage logging as anthropogenic disturbance and GFWC has adopted the same method. There were also comments on analysis in the draft report that focused on caribou and on ecodistricts. GFWC decided to simplify this bulletin to a more focused analysis of disturbance. We hope to address the issue of natural and anthropogenic disturbances and caribou at a later date.

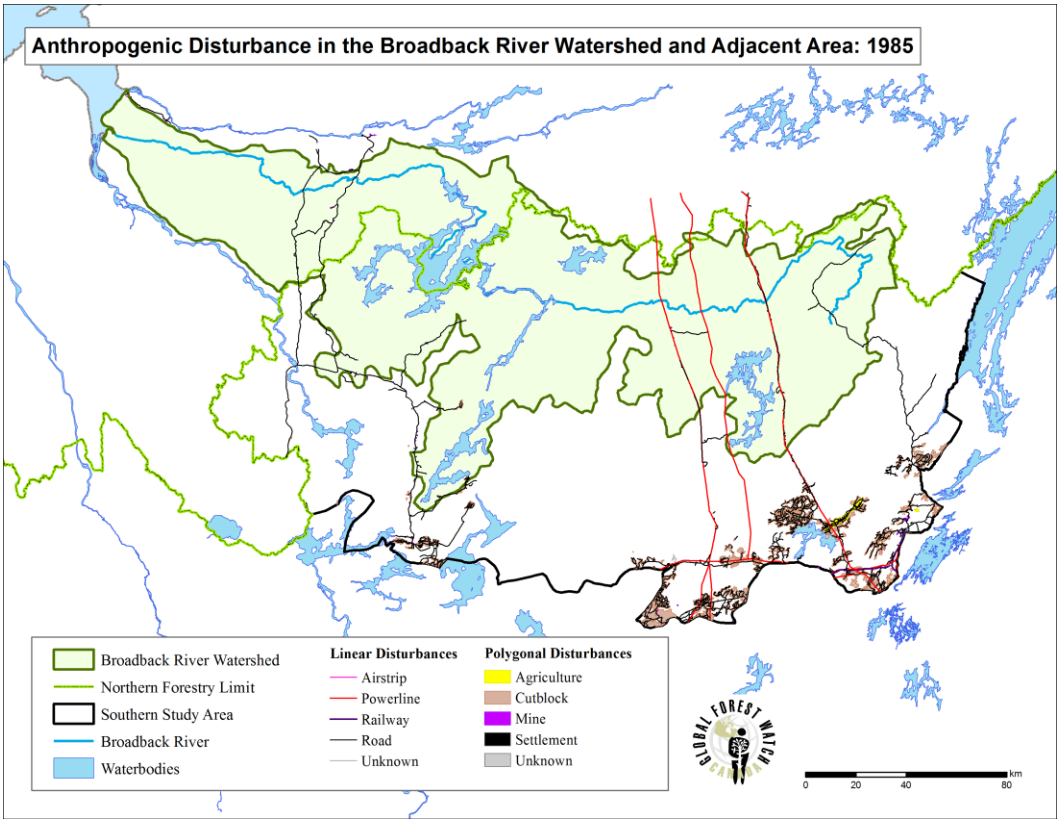
As per GFWC's open data policy, we are making our disturbance datasets available under an open data licence, with a request for attribution.

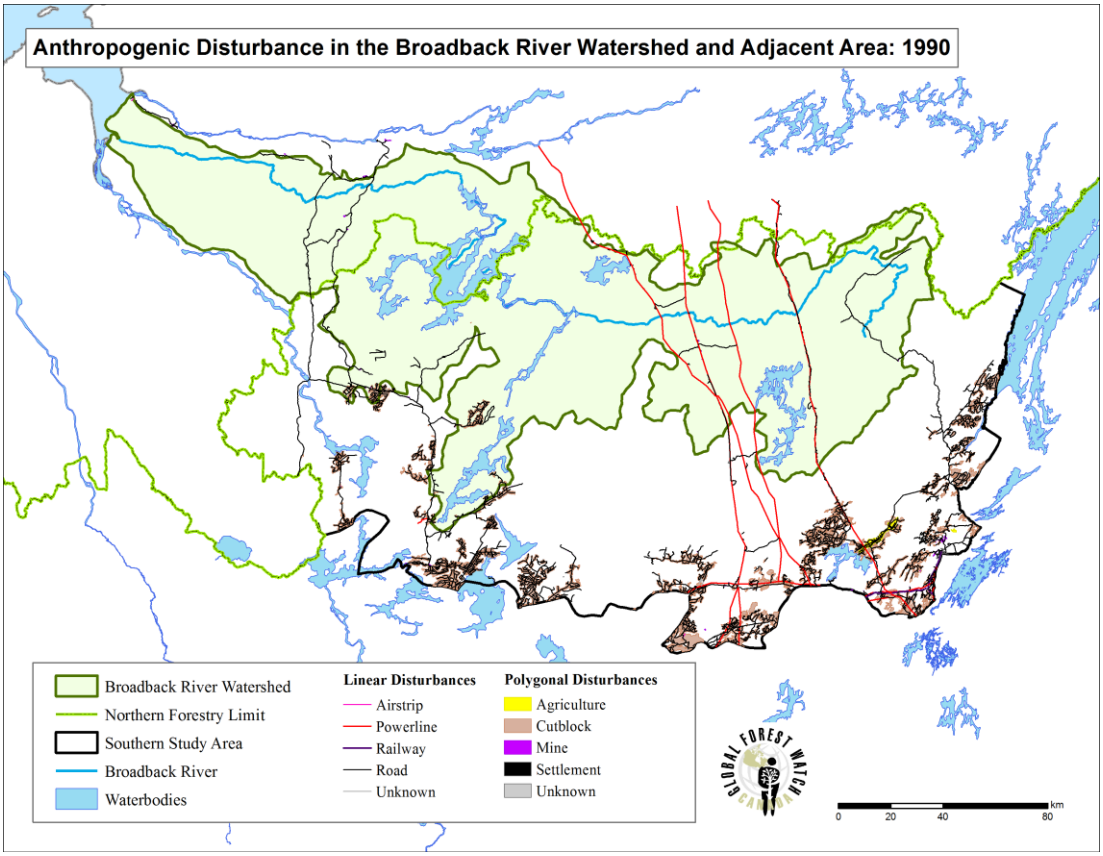
Appendix 1. Landsat Imagery Used in Time-Series Disturbance Mapping

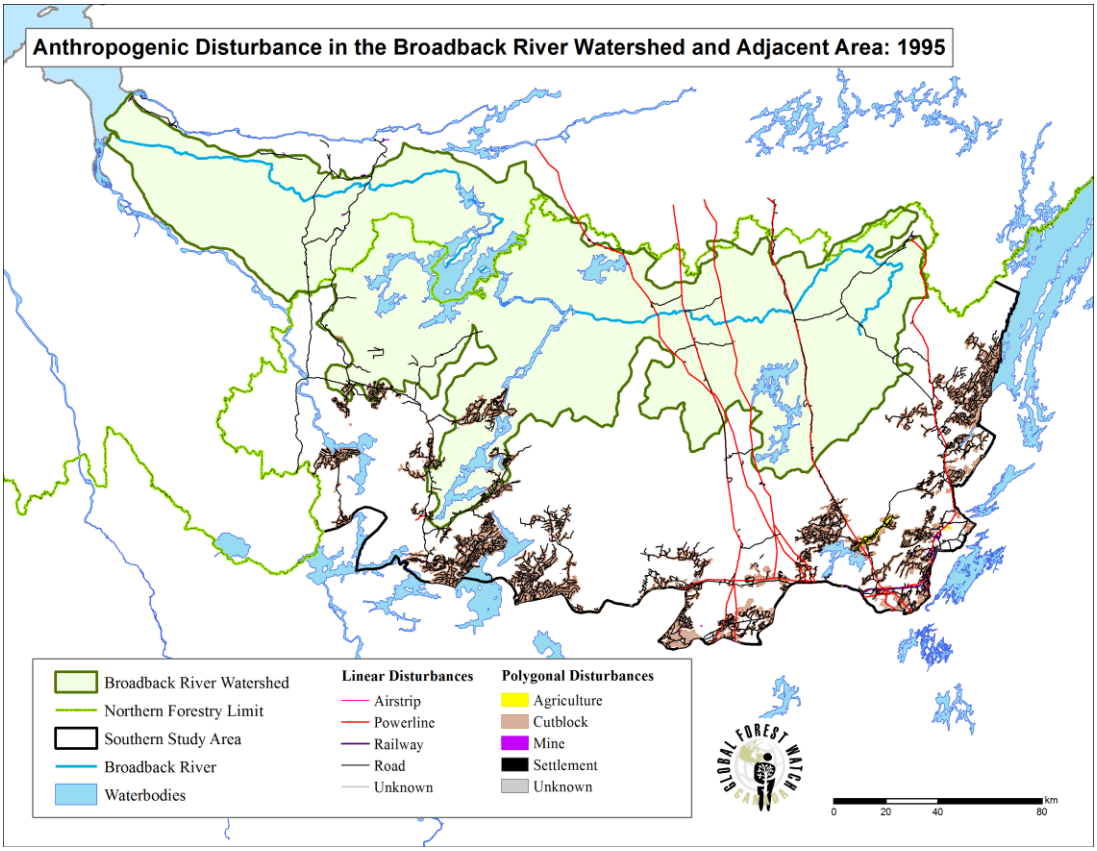
Period	Platform	Path	Row	Date 1	Date 2	Period	Platform	Path	Row	Date 1	Date 2
1980	Landsat 2	17	24	6/29/1980		2000	Landsat 7	16	24	10/9/2000	8/22/2000
	Landsat 2	17	25	6/29/1980			Landsat 7	16	25	6/3/2000	
	Landsat 2	18	24	8/23/1980			Landsat 7	17	24	6/26/2000	
	Landsat 2	18	25	8/23/1980	6/30/1980		Landsat 5	17	25	8/5/2000	
	Landsat 2	20	24	7/2/1980			Landsat 7	18	24	8/20/2000	
	Landsat 2	20	25	7/2/1980			Landsat 7	18	25	8/20/2000	
1985	Landsat 5	16	24	7/20/1985			Landsat 7	19	24	8/27/2000	
	Landsat 5	16	25	7/4/1985			Landsat 7	19	25	8/27/2000	
	Landsat 4	17	24	8/4/1985	7/19/1985	2005	Landsat 5	16	24	6/9/2005	
	Landsat 5	17	25	10/31/1985			Landsat 5	16	25	5/24/2005	
	Landsat 5	18	24	10/22/1985			Landsat 5	17	24	8/3/2005	
	Landsat 5	18	25	10/22/1985			Landsat 5	17	25	5/31/2005	
	Landsat 5	19	25	5/6/1985			Landsat 5	18	24	5/22/2005	
	Landsat 5	19	24	8/29/1985			Landsat 5	18	25	8/26/2005	
1990	Landsat 5	16	24	6/16/1990			Landsat 5	19	24	5/29/2005	
	Landsat 5	16	25	8/3/1990			Landsat 5	19	25	6/30/2005	
	Landsat 5	17	24	9/11/1990		2010	Landsat 5	16	24	9/11/2010	
	Landsat 5	17	25	9/11/1990			Landsat 5	16	25	9/11/2010	
	Landsat 5	18	24	6/30/1990			Landsat 5	17	24	6/24/2010	
	Landsat 5	18	25	9/18/1990			Landsat 5	17	25	10/4/2010	
	Landsat 5	19	25	5/4/1990			Landsat 5	18	24	6/5/2010	
	Landsat 5	19	24	7/7/1990			Landsat 5	18	25	6/21/2010	
1995	Landsat 5	16	24	6/14/1995			Landsat 5	19	24	7/14/2010	
	Landsat 5	16	25	6/14/1995			Landsat 5	19	25	5/11/2010	
	Landsat 5	17	24	6/21/1995		2015	Landsat 8	16	24	8/8/2015	
	Landsat 5	17	25	6/21/1995			Landsat 8	16	25	5/20/2015	
	Landsat 5	18	24	5/27/1995			Landsat 7	16	25	6/13/2015	
	Landsat 5	18	25	5/27/1995			Landsat 8	17	24	9/16/2015	
	Landsat 5	19	24	8/6/1995			Landsat 8	17	25	9/16/2015	
	Landsat 5	19	25	8/6/1995			Landsat 8	18	24	7/5/2015	
							Landsat 8	18	25	8/22/2015	
							Landsat 8	19	24	5/25/2015	
							Landsat 8	19	25	7/28/2015	

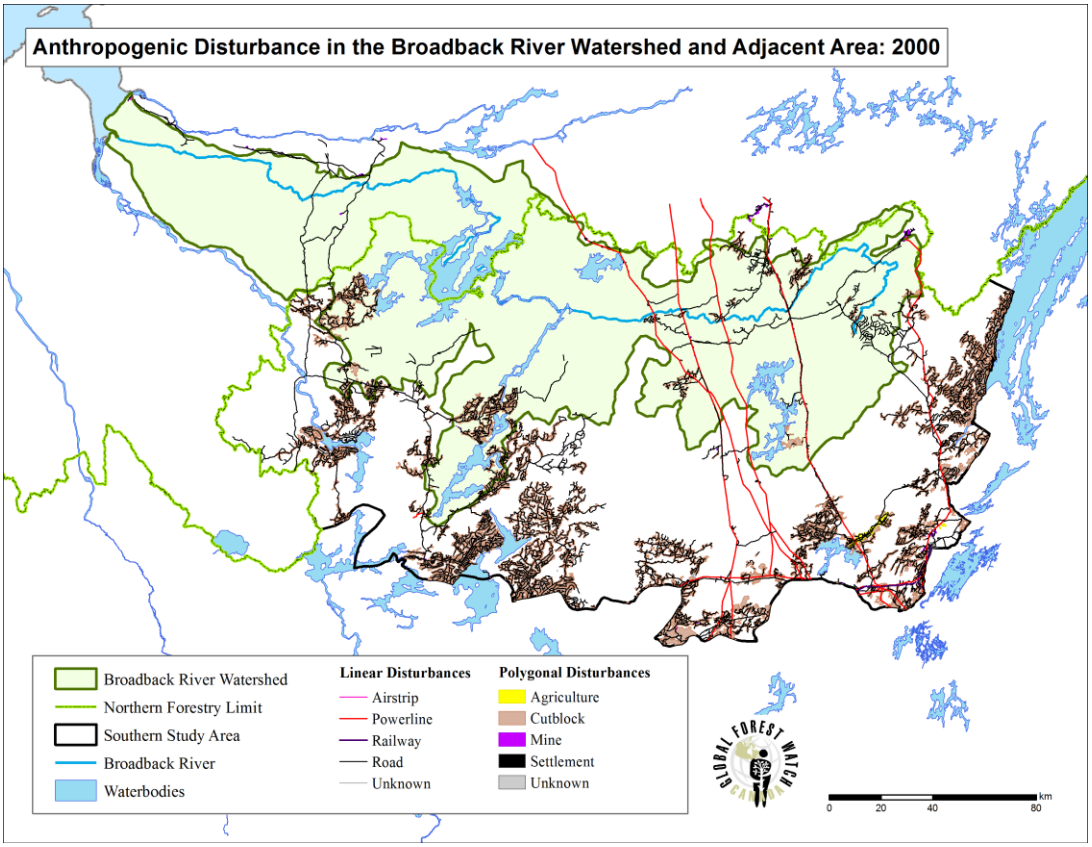
Appendix 2. Time-Series Maps: Broadback River Watershed and Adjacent Area

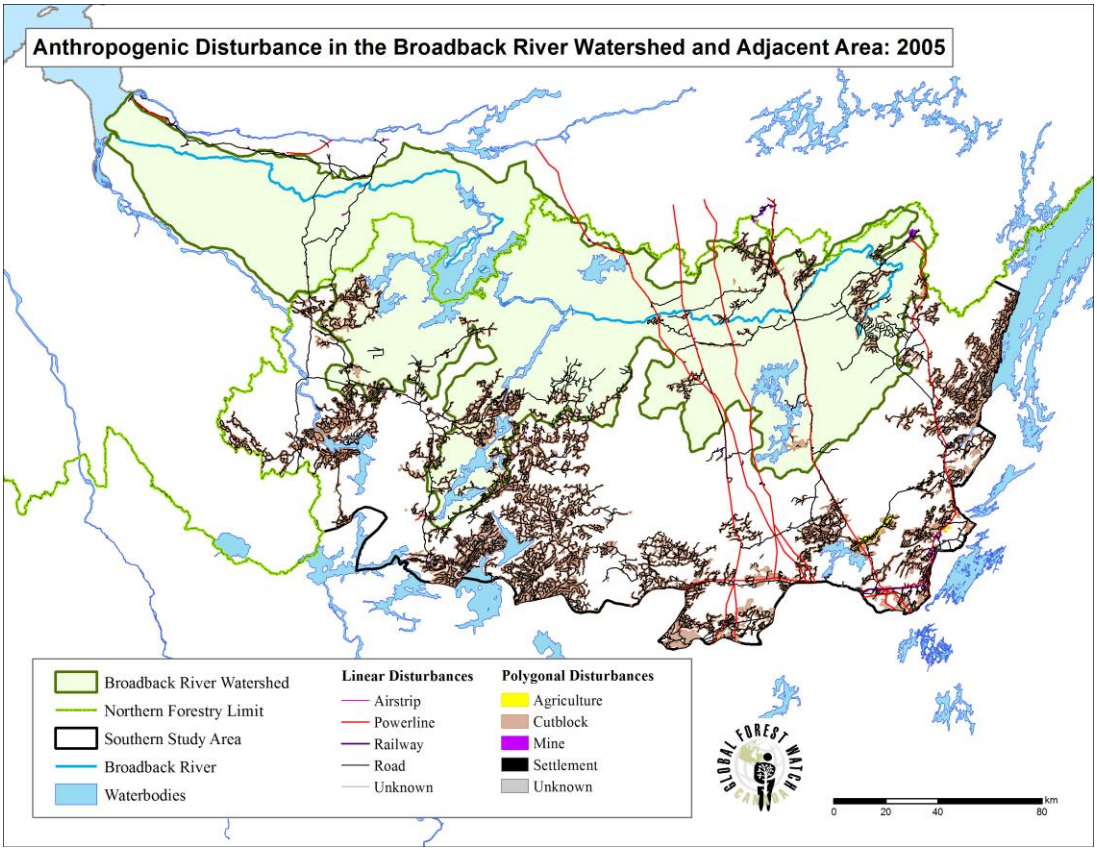


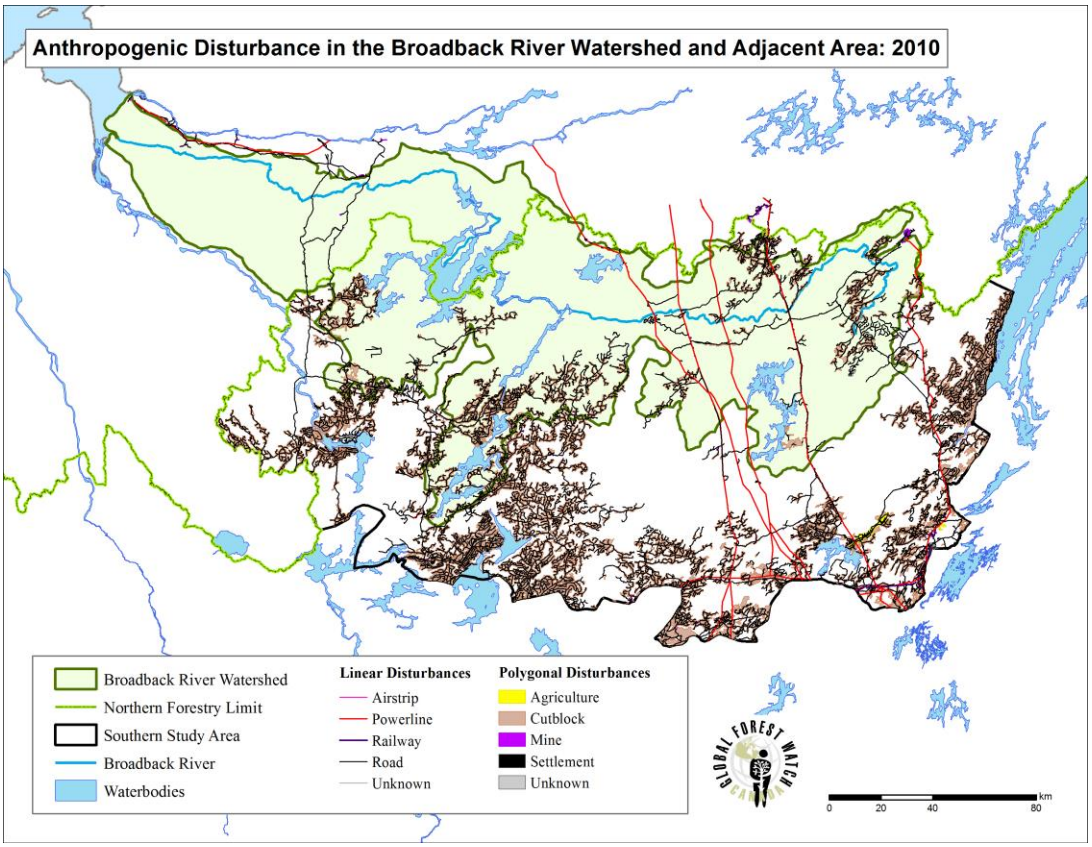


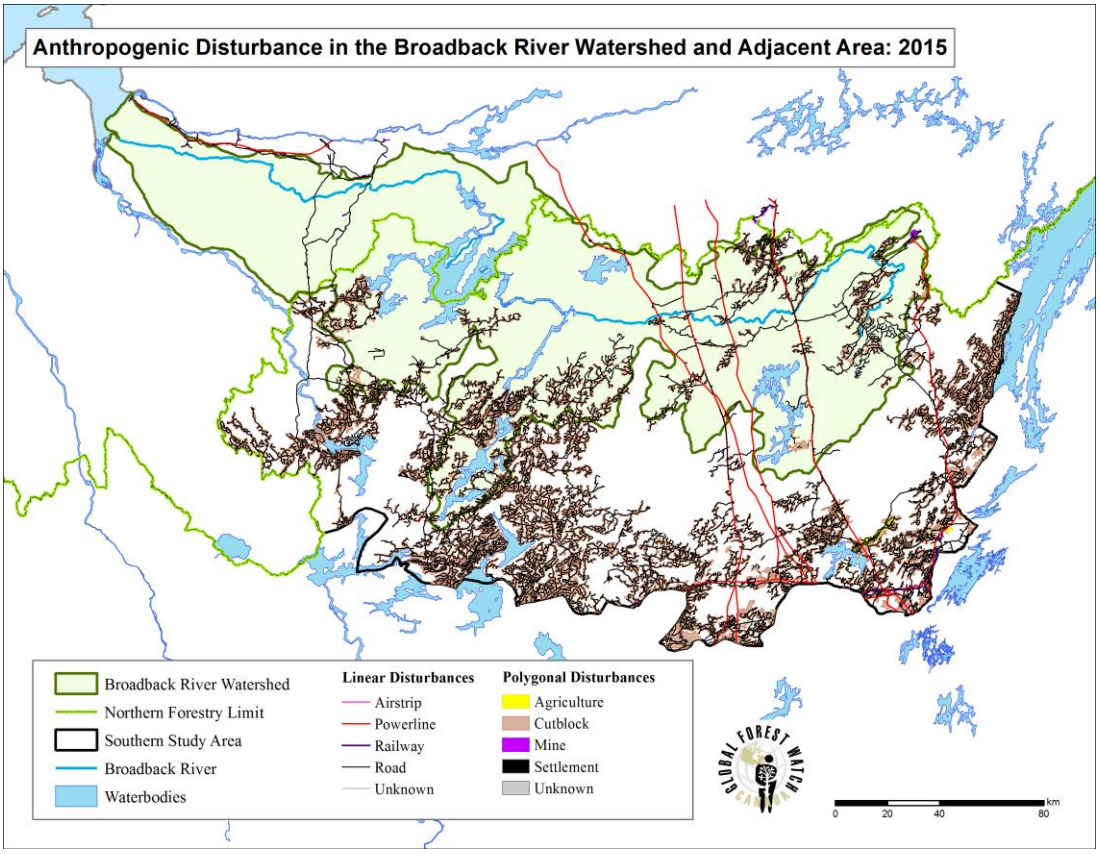

Anthropogenic Disturbance in the Broadback River Watershed and Adjacent Area: 1990
Broadback River Watershed
Northern Forestry Limit
Southern Study Area
Broadback River
Waterbodies
Linear Disturbances
Airstrip
Powerline
Railway
Road
Unknown
Polygonal Disturbances
Agriculture
Cutblock
Mine
Settlement
Unknown
0 20 40 80
km


Anthropogenic Disturbance in the Broadback River Watershed and Adjacent Area: 1995
Broadback River Watershed
Northern Forestry Limit
Southern Study Area
Broadback River
Waterbodies
Linear Disturbances
Airstrip
Powerline
Railway
Road
Unknown
Polygonal Disturbances
Agriculture
Cutblock
Mine
Settlement
Unknown
0 20 40 80
km

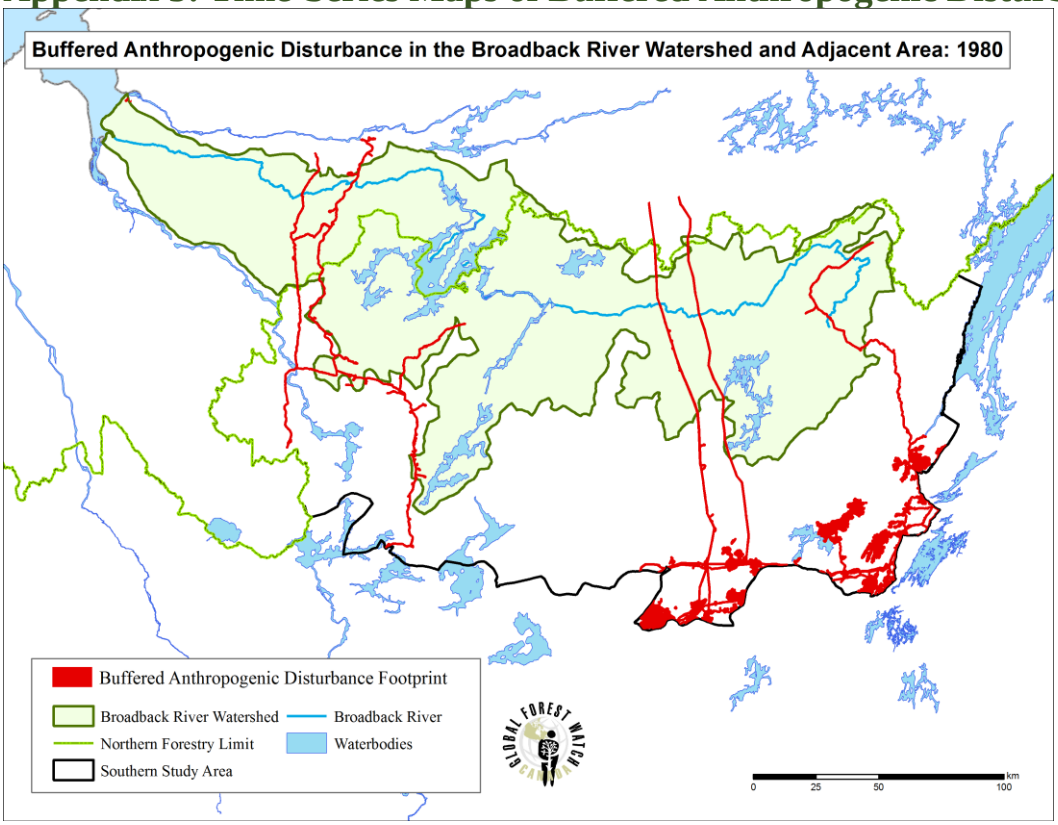

Anthropogenic Disturbance in the Broadback River Watershed and Adjacent Area: 2000
Broadback River Watershed
Northern Forestry Limit
Southern Study Area
Broadback River
Waterbodies
Linear Disturbances
Airstrip
Powerline
Railway
Road
Unknown
Polygonal Disturbances
Agriculture
Cutblock
Mine
Settlement
Unknown
0 20 40 80
km

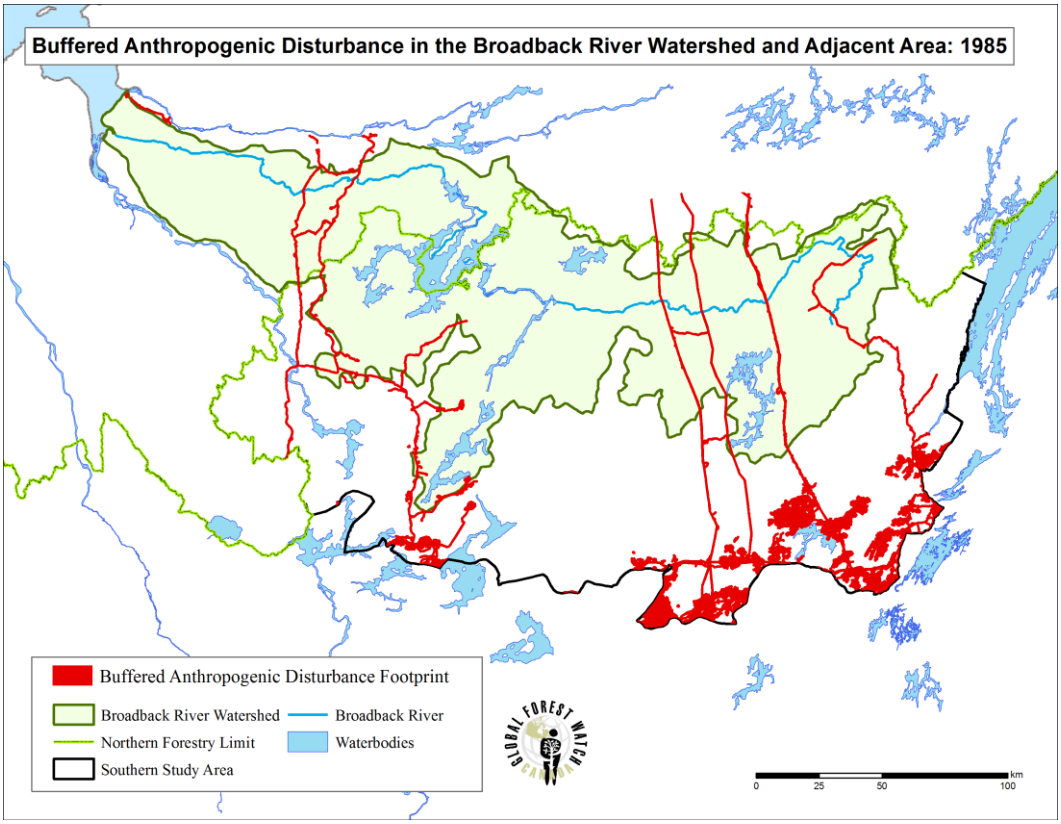

Anthropogenic Disturbance in the Broadback River Watershed and Adjacent Area: 2005
Broadback River Watershed
Northern Forestry Limit
Southern Study Area
Broadback River
Waterbodies
Linear Disturbances
Airstrip
Powerline
Railway
Road
Unknown
Polygonal Disturbances
Agriculture
Cutblock
Mine
Settlement
Unknown
0 20 40 80
km

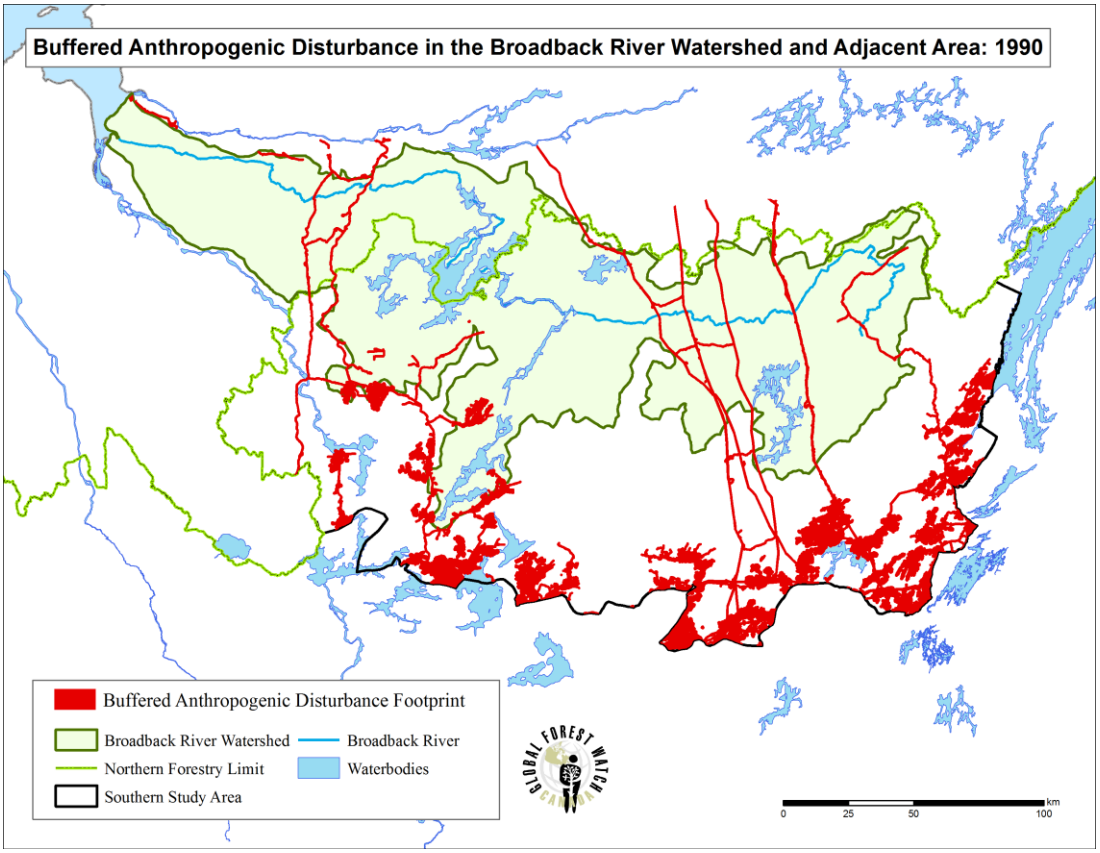

Anthropogenic Disturbance in the Broadback River Watershed and Adjacent Area: 2010
Broadback River Watershed
Northern Forestry Limit
Southern Study Area
Broadback River
Waterbodies
Linear Disturbances
Airstrip
Powerline
Railway
Road
Unknown
Polygonal Disturbances
Agriculture
Cutblock
Mine
Settlement
Unknown
0 20 40 80
km

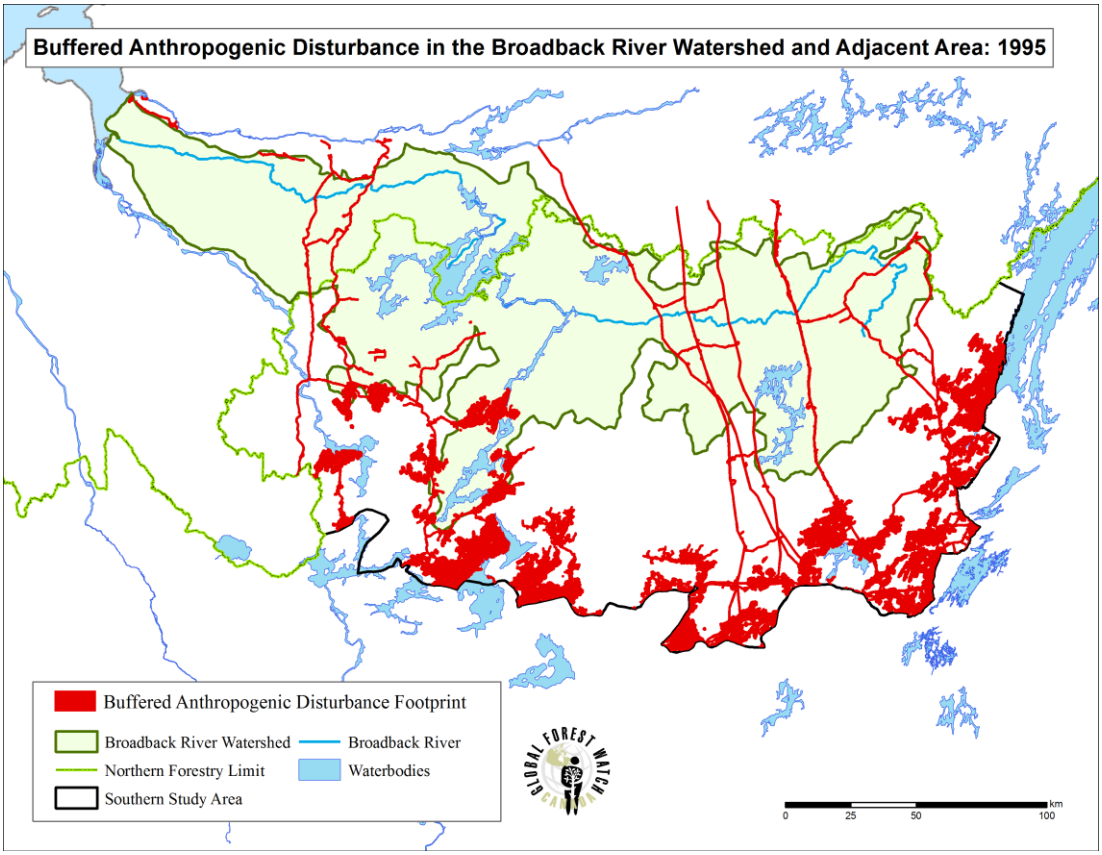

Anthropogenic Disturbance in the Broadback River Watershed and Adjacent Area: 2015
Broadback River Watershed
Northern Forestry Limit
Southern Study Area
Broadback River
Waterbodies
Linear Disturbances
Airstrip
Powerline
Railway
Road
Unknown
Polygonal Disturbances
Agriculture
Cutblock
Mine
Settlement
Unknown
0 20 40 80
km

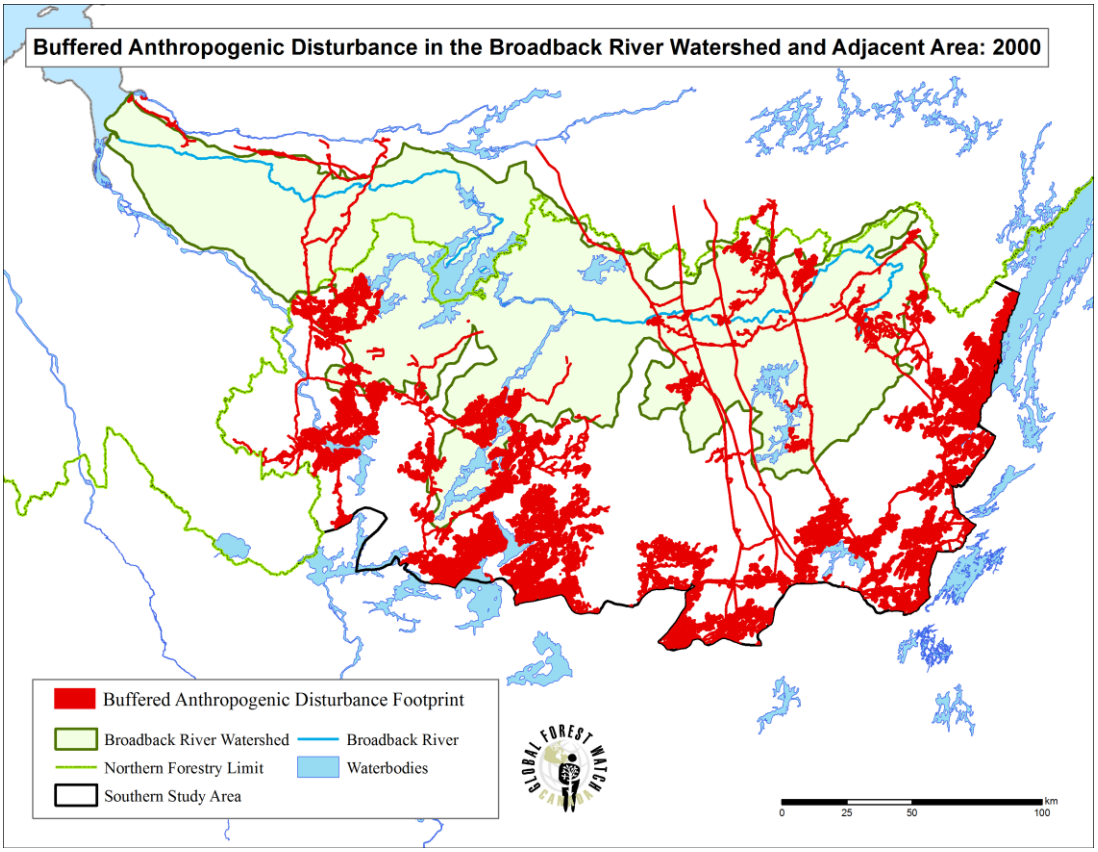
Appendix 3: Time-Series Maps of Buffered Anthropogenic Disturbance

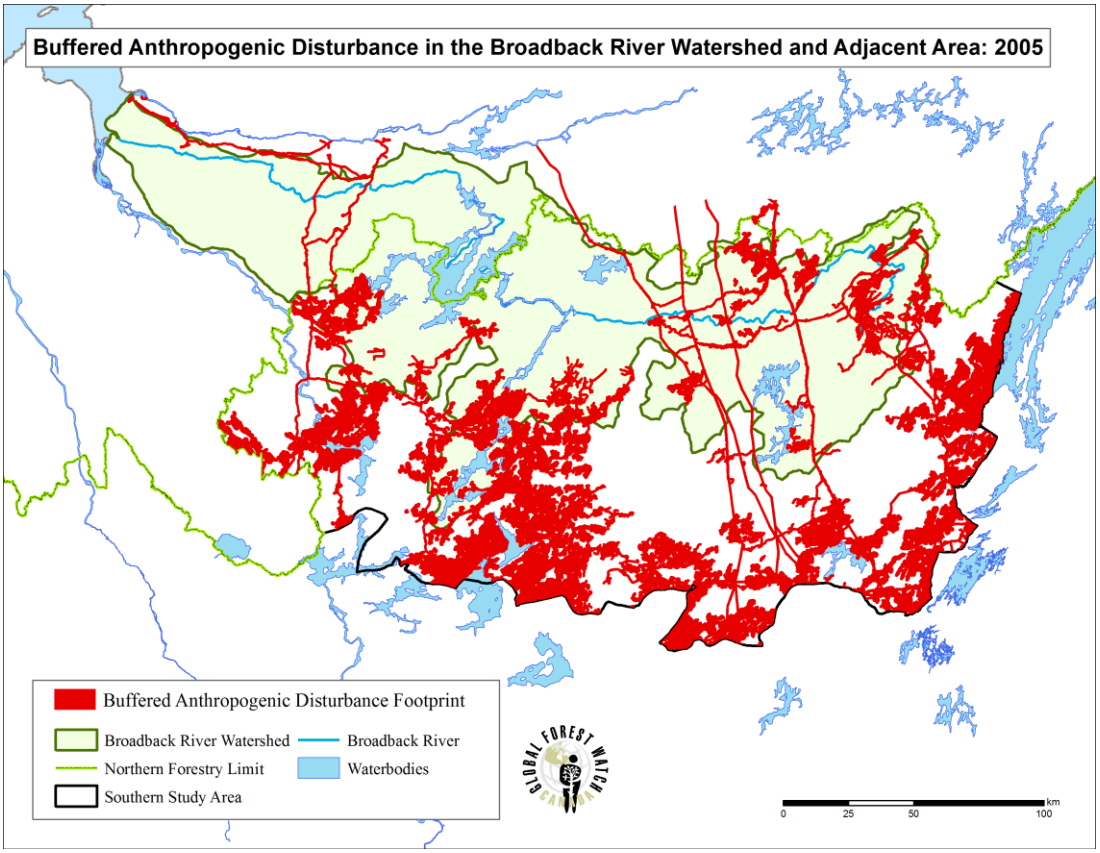


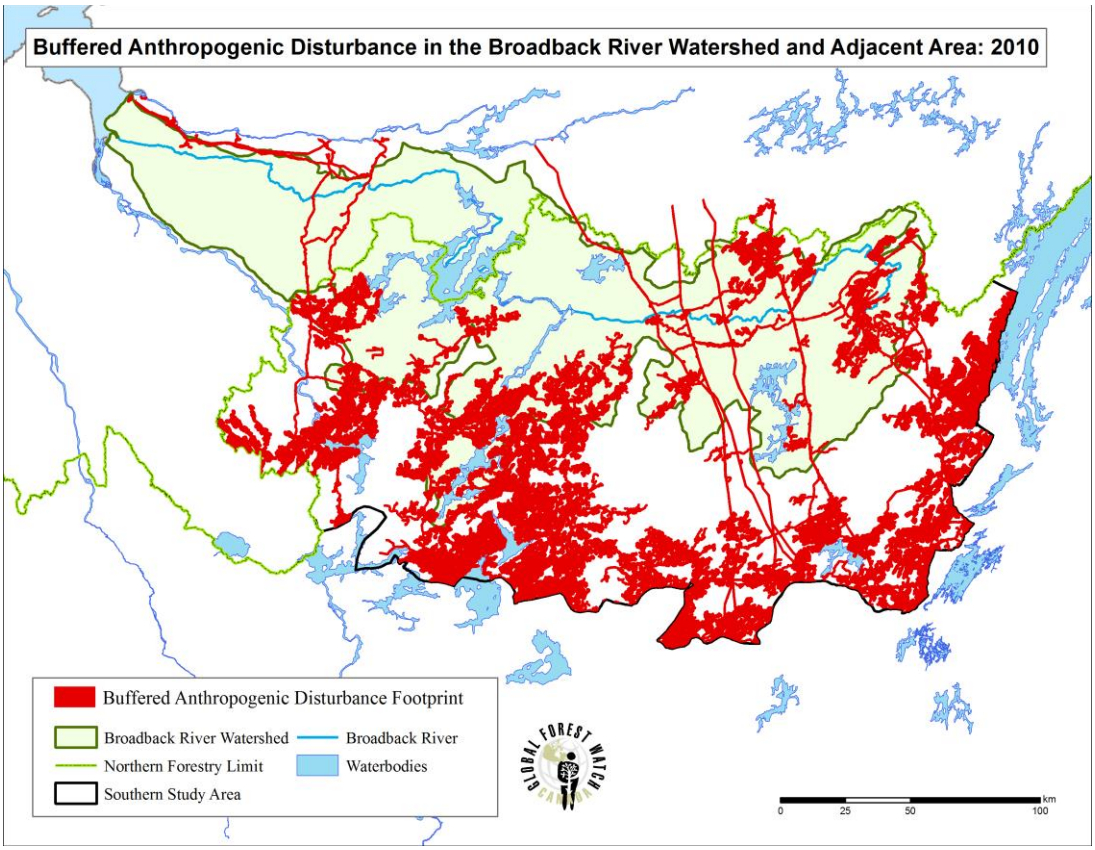


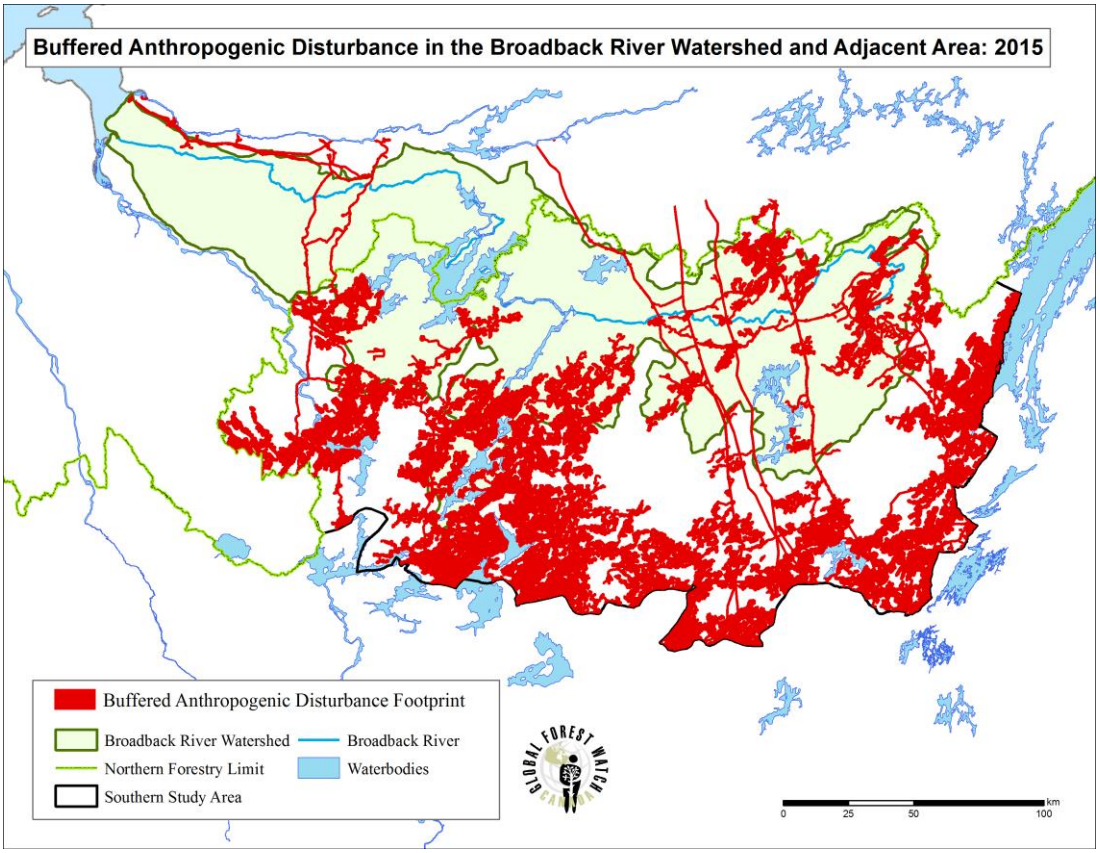

Buffered Anthropogenic Disturbance in the Broadback River Watershed and Adjacent Area: 1990
Buffered Anthropogenic Disturbance Footprint
Broadback River Watershed
Broadback River
Northern Forestry Limit
Waterbodies
Southern Study Area
0
25
50
100
km


Buffered Anthropogenic Disturbance in the Broadback River Watershed and Adjacent Area: 1995
Buffered Anthropogenic Disturbance Footprint
Broadback River Watershed
Broadback River
Northern Forestry Limit
Waterbodies
Southern Study Area
0
25
50
100
km


Buffered Anthropogenic Disturbance in the Broadback River Watershed and Adjacent Area: 2000
Buffered Anthropogenic Disturbance Footprint
Broadback River Watershed
Broadback River
Northern Forestry Limit
Waterbodies
Southern Study Area
0
25
50
100
km


Buffered Anthropogenic Disturbance in the Broadback River Watershed and Adjacent Area: 2005
Buffered Anthropogenic Disturbance Footprint
Broadback River Watershed
Broadback River
Northern Forestry Limit
Waterbodies
Southern Study Area
0
25
50
100
km


Buffered Anthropogenic Disturbance in the Broadback River Watershed and Adjacent Area: 2010
Buffered Anthropogenic Disturbance Footprint
Broadback River Watershed
Broadback River
Northern Forestry Limit
Waterbodies
Southern Study Area
0
25
50
100
km


Buffered Anthropogenic Disturbance in the Broadback River Watershed and Adjacent Area: 2015
Buffered Anthropogenic Disturbance Footprint
Broadback River Watershed
Broadback River
Northern Forestry Limit
Waterbodies
Southern Study Area
0
25
50
100
km